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غير مصرح بتداول هذا الكتاب خارج وزارة التربية والتعليم والتعليم الفنى

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مقدمة الكتاب

أبناءنا وبناتنا طلاب الصف الأول الثانوى ، شهدت الأعوام الأخيرة طفرات هائلة ومستحدثات تكنولوجية فى شتى مجالات الحياة ، وكان على المنظومة التعليمية بجمهورية مصر العربية أن تواكب هذه المستحدثات متأثرةً بهذا التطور الهائل.

لذلك حرصت وزارة التربية والتعليم على تطوير المناهج على اعتبار أن المنهج كائن يلزمه التجديد والتحديث ليتوافق مع متغيرات العصر وذلك بهدف إعداد جيل قادر على مواكبة هذه المستحدثات ، بل تكون له القدرة على استخدامها فى ابتكار ما هو أحدث.

وقد راعينا فى إعداد هذا الكتاب تغيير دور المتعلم لنخرج به من حيز المتلقى إلى مجال المتفاعل النشط من خلال قيامه بالبحث والاستقصاء والمقارنة والاستنباط واكتساب المهارات وغرس حب المعرفة حتى يصبح فردًا فعالًا فى المجتمع ؛ وذلك لتحقيق الاكتفاء الذاتى لوطنه اقتصاديًّا وثقافيًّا واجتماعيًّا ، وذلك من خلال التنوع فى الأنشطة والمهارات بهدف إعداد جيل متنوع من الطلاب يخدم الوطن فى كافة المجالات .

ويتضمن الكتاب أنشطة فردية وجماعية ، معملية وتطبيقية لتحقيق أهداف المنهج. وينتهى كل فصل بأنشطة تقويمية حتى يقف الطالب على ما تَحقق من أهداف وما يجب القيام به من أعمال لتحقيق ما لم يتم تحقيقه ، وقد راعينا فى إعداد هذا الكتاب التسلسل المنطقى لأبواب المنهج ، وكذلك التدرج فى مستوى هذه الأنشطة مراعاة للفروق الفردية والحاجات والميول المختلفة.

وقد تم عرض هذا المنهج فى شكل نسيج متكامل ومترابط فى ستة أبواب تبدأ بعلم الكيمياء وطبيعته وعلاقته بالعلوم الأخرى ، وخاصة الحديث منها مثل : علم النانو تكنولوجى ، ثم توالت أبواب المنهج مرورًا بالكيمياء الكمية ثم المحاليل والأحماض والقواعد ، يليها الكيمياء الحرارية ، ثم الكيمياء النووية.

وقد تم تزويد الكتاب بروابط على بنك المعرفة المصرى

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منها ما هو فى سياق الموضوعات ، ومنها ما هو إثرائى لتعميق المعرفة والفهم تشجيعًا لكم على المزيد من البحث والاطلاع.

ونحن إذ نقدم هذا الكتاب لكم نتمنى أن يحقق ما تصبو إليه رغباتكم ويشبع ميولكم ويلبى احتياجاتكم ، متمنين أن يتحقق لمصرنا الغالية الرخاء والإزدهار.

والله ولى التوفيق ،

المعدون

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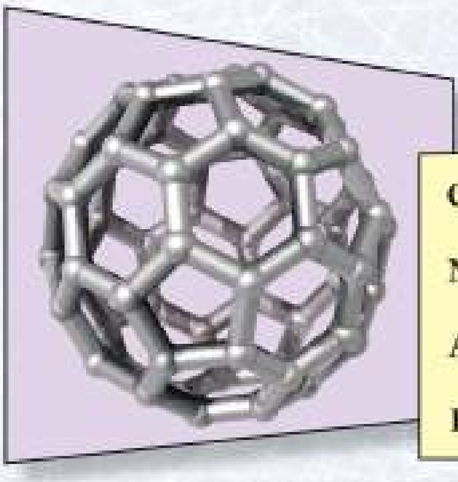

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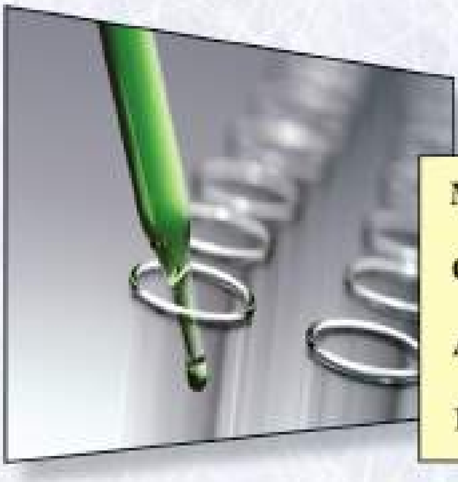

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Unit One

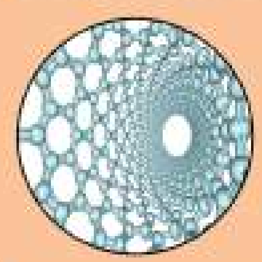
General objectives of unit one :

By the end of this unit, the student will be able to :

- Identify what is chemistry.
- Explain the relationship between chemistry and the other branches of science.
- Identify the nature of measurement and its importance.
- Know the tools and apparatuses used in chemistry labs.
- Use practical tools which suitable for the curriculum with accuracy and efficiency.
- Understand the concept of nanotechnology.
- Understand the concept of nanochemistry.
- Specify some of the applications of the chemistry of nanotechnology.
- Conclude that some of the applications of nanotechnology have useful effects while others are harmful.

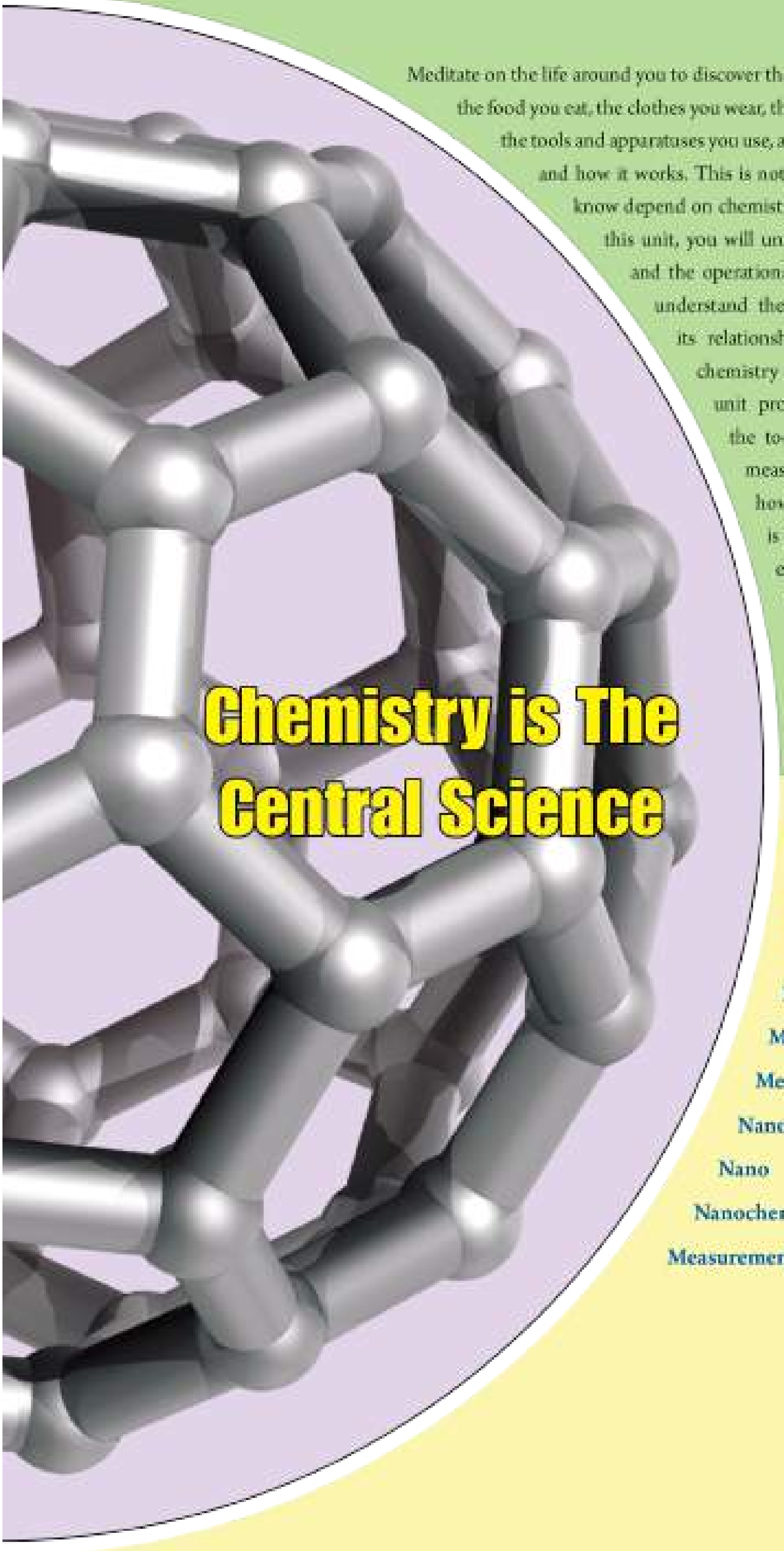
Unit One lessons :

(1) Chemistry and Measurement



(2) Nanotechnology and Chemistry

Involved Issues : Science, Technology, and Society



Chemistry is The Central Science

Meditate on the life around you to discover that chemistry interferes in everything; the food you eat, the clothes you wear, the medicine the doctor writes for you, the tools and apparatuses you use, and even in the structure of our bodies and how it works. This is not all, as many of the sciences that we know depend on chemistry in explaining their phenomena. In this unit, you will understand the fieldwork of chemistry and the operations that chemists follow. You will also understand the role of chemistry in our life and its relationship with the other sciences. Since chemistry depends on experimentation, this unit provides you with the knowledge of the tools and apparatuses that is used in measurement and experimentation, and how to use it efficiently. If the next era is the era of very small substances with extraordinary properties, in other words, the era of nanotechnology, then we may consider it the era of chemistry, as it is responsible for building and discovering these types of substances.

Key Terms :

- Physical Sciences
- Biochemistry
- Physical chemistry
- Measurement
- Measurement unit
- Nanotechnology
- Nano
- Nanochemistry
- Measurement Instrument

Lesson One : Chemistry and Measurement

Learning Outcomes

By the end of this lesson, you will be able to:

- ✓ Identify what is chemistry.
- ✓ Understand the role of chemistry in our life.
- ✓ Explain the relationship between chemistry and the rest of the branches of science.
- ✓ Identify the nature of measurement and its importance.
- ✓ Know the tools and apparatuses used in chemistry labs.
- ✓ Use the appropriate and practical tools of the curriculum with accuracy and efficiency.
- ✓ Identify and use minute tools and apparatuses.

Figure (1) Physical Sciences

Chemistry

Humans live their life searching and exploring their surrounding universe in a constant and relentless attempt to understand the phenomena of this universe, to explain it, and to even control it. These efforts exerted by humans have come with positive results and will continue to positively result in facts, concepts, principles, laws, and theories that are coordinated in a structure which is science.

> Science: an organized structure of knowledge that includes facts, concepts, principles, laws, scientific theories, and an organized method in research and investigation.

The field of science differs with the different phenomena under study, the tools used, and the methods used in research. One of these sciences is chemistry.

> Chemistry: the science that is interested in studying the substance's composition, its properties, changes that occur to it, the reactions of different substances with each other, and the suitable conditions for this.

Chemistry is one of the physical sciences (figure 1) that man has know and applied since long ago. This science has been connected, since ancient civilizations, with metals, mining, the production of colors, medicine, and some technical industries such as tanning, dying clothes, and the production of glass. The ancient Egyptians used it in mummifying their dead. Chemistry now has a role in all the fields of life.

The fields of studying chemistry :

Chemists are interested in studying the molecular and atomic structure of substances, how they bind with each other, in order to understand their chemical properties, and describe them quantitatively and qualitatively. Also the chemical reactions in which a substance transforms into another substance and how to control it. As chemists are always trying to reach new beneficial products that satisfy the increasing needs in different fields like medicine, agriculture, engineering, and industry. Chemistry also contributes in treating some environmental problems like rust, pollution of water - air - soil , water shortage, energy resources, and many other fields.

Chemistry has hence been divided into branches like physical chemistry – biochemistry – organic chemistry – analytical chemistry – thermochemistry – nuclear chemistry – electrical chemistry – environmental chemistry, and others.

Chemistry is the central science

Search for yourself

Refer to the Internet and clarify the relationship between chemistry and the following applications :

Figure (2) The relationship between chemistry and life

Chemistry is considered the center of most other sciences like biology, physics, medicine, agriculture and other sciences. We can mention some of them, for example, as follows:

Chemistry and biology:

Biology is a science specialized in studying organisms, chemistry is involved in understanding the chemical reactions that occur inside the organisms that include the reactions of digestion, respiration, photosynthesis and others. The combination between biology and chemistry results in the science of biochemistry. It is specialized in the studying of the chemical structure of the parts of the cell in the various organisms like fats, carbohydrates, proteins, nucleic acids and others.

Chemistry and Physics :

Physics is the science that studies all what relates to the matter, its movement, energy, in order to understand the natural phenomena and the Affecting force on it. Physics also studies measurement and inventing new methods for measuring with more accuracy. The combination between physics and chemistry is called physical chemistry. It specializes in the study of the properties of substances, their structures, and the particles that form these substances, which allows the physicists to perform their studies in an easier method.

Chemistry, Medicine, and Pharmacy :

The medicines that patients use and doctors prescribe are chemical substances that have healing properties. Chemists either prepare these substances in their laboratories or they extracted them from natural sources. Chemistry explains the nature of the function of hormones and enzymes in the human body and how medicine is used in treating the defect in any of them.

Chemistry and Agriculture :

Chemistry contributes in the selection of the suitable soil to plant any crop by chemical analysis, which specifies the ratios of its components and the degree of sufficiency of these components for the needs of these crops. Chemistry also specifies the suitable fertilizer for this soil to increase its productivity of crops. It also contributes in the production of suitable insecticides for agricultural insects.

Chemistry and the Future :

Through Nanochemistry, substances can be discovered and formed with extraordinary(unusual) properties using nanotechnology chemistry. These substances may be used for the advancement of various fields like engineering, communication, medicine, the environment, transportation, and provide numerous human needs.

Measurement in Chemistry

The nature of measurement :

The scientific, industrial, technological, and economical advancement that we live now is the result of the correct and accurate use of the measurement principles.

Measurement: the comparison of an unknown quantity with another quantity of its kind in order to know the number of times which the first includes the second.

The measurement process involves two main points, which are :

- **Numerical value:** through which we describe the distance or the measured property.
- **Suitable measuring unit:** is agreed upon in it the form of the International System of Units. It is a certain portion of a certain physical amount used as an indicator to measure an actual portion for this amount.

Numerical value	Measuring unit
5	kg
10	m
100	sec

Enrichment Information

The French scientist, Antoine Lavoisier, is considered responsible for making chemistry a precise quantitative science. As his experiments were completely of the quantitative type. He was the first to identify the composition of the phosphoric acid and nitric acid. Lavoisier wrote the law of conservation of mass. His work gave a strong push toward the advancement of the measuring tools and apparatuses in chemistry.

The importance of measurement in chemistry

The methods of analyzing and measuring in chemistry, at the present time, have become more advanced in terms of precision and variety. Humans have become dependent on them in all the fields of life including the environment, food, health, agriculture, industry and others. The importance of measurement in chemistry is due to the fact that it provides us with necessary information and quantitative data to allow us to use the required procedures and the appropriate practices.

1. Measurement is necessary for gaining information on the type and concentration of the elements forming the substances that we use and deal with.

Test your Skills

The following table shows the components of two bottles of mineral water expressed in mg/L unit.

Components	Na^+	K^+	Mg^{++}	Ca^{++}	Cl^-	$(HCO_3)^-$	$(SO_4)^{2-}$
Bottle (A)	25.5	2.8	8.7	12	14.2	103.7	41.7
Bottle (B)	120	8	40	70	220	335	20

Carefully read the table and then answer the following questions:

- If you knew that a consumer follows a nutritional system that is low on salt – which bottle will he choose?
- A person has consumed 1.5 liters of water during a day from bottle (B). Calculate the mass of calcium that he gets from water during the day.
- What is the importance of information card to the consumer? Is measurement necessary in our life?

2. Measurement is necessary for monitoring and protection.

The following table specifies the international standards to decide the usability of water. Use the given information in the table to decide the quality of water in the two previous cards.

Components	Na^+	K^+	Mg^{++}	Ca^{++}	Cl^-	$(SO_4)^{2-}$
Quantity (mg/L)	less than 150	less than 12	less than 50	less than 300	200 - 250	less than 250

The safety of the environment and its protection requires the monitoring of drinking water, the air we breathe, food substances, and agricultural products. This requires many various measurements.

3. Measurement is necessary to evaluate a certain situation and to suggest a medication in the case of the presence of defects.

Test your Skills

The medical analysis report in front of you represents results of medical biological analyses in which a person was subjected to before breakfast. Clarify the following:

- What does the reference value mean?
- What do you conclude from the results of the sugar (glucose) and uricacid in the blood of this person?
- What are the decisions that man should take in the light of your deduction?
- What are the decisions that this person has to take in the light of your deduction?

Medical Analysis Report

Reference value	Value of analysis (mg/dL)	Type of analysis (mg/dL)
70 – 110	70	Glucose
3.6 – 8.3	9.2	Uricacid

In medical analysis, measurements allow us to take the necessary decisions to cure the defect.

Measurement tools in the chemical laboratory :

Chemical experiments are carried out in a place with certain specifications and conditions. This place is called a lab or a chemical laboratory. A chemical laboratory requires appropriate safety procedures, a source of heat like a bunzen flame , a source of water, and places to store chemicals, tools, and various apparatuses.It is necessary to know the correct method to use each of them and how to store them.The following is a detailed display of some of the tools and apparatuses that are used in the chemical laboratory and why it is used:

resistant

Graduated Cylinder :

A graduated cylinder is made out of glass or plastic. It is used to measure the volume of liquids where it is more accurate than flasks. There are different capacities of graduated cylinders.

Figure (7) How to determine the volume of a liquid in a cylinder

Figure (8) Graduated cylinders with different capacities

Check Your Understanding

How do you use a graduated cylinder in determining the size of a solid body that does not dissolve ?

Flasks :

Flasks are one of the types of glass tools used in a chemistry lab. There are different types of flasks according to its function:

- Conical flask : It is made out of Pyrex glass. Their types differ accordingly with the difference in flask capacity. They are used in the titration process.
- Round-Bottom Flask : It is usually made out of Pyrex glass. Their types differ accordingly with the difference in flask capacity. They are used in the processes of preparation and distillation.
- Volumetric Flask : It is made out of Pyrex glass. On its top, it has a mark that determines the flask volume capacity and it is used for preparing the standard solutions (with known concentrations very accurately).

Figure (9) Conical flask

Figure (10) Round flask

Figure (11) Volumetric flask

The measurement process involves two main points, which are :

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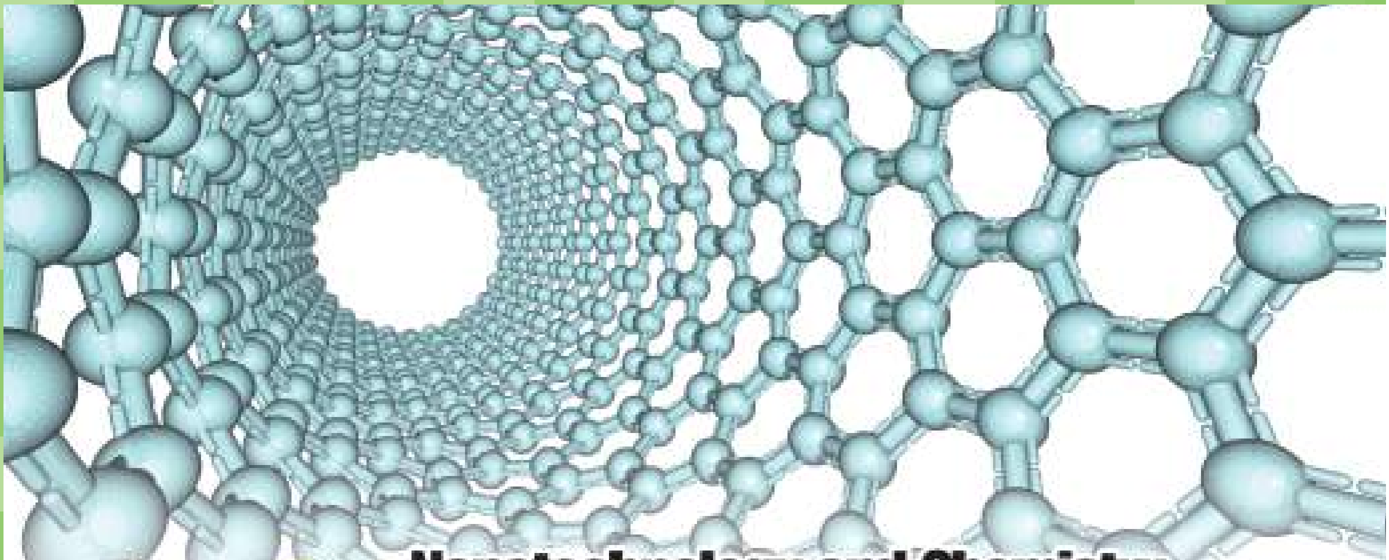


Lesson Two : Nanotechnology and Chemistry

Learning Outcomes

By the end of this lesson, you will be able to:

- ✓ Understand the concept of nanotechnology.
- ✓ Mention some of the applications of nanotechnology chemistry.
- ✓ Conclude the beneficial and harmful effects of nanotechnology.

What is meant by nanotechnology ?

Nanotechnology is a term of two words: the first word is "Nano" and derives from the Greek word "Nanos" and it means "Dwarf" or something very small. The second word is "Technology" and it means application of knowledge in a certain field.

> Nanotechnology: the technology of very small substances, and it specializes in treating the substance on the Nano measure to produce new, useful, and unique resultants in its properties.

Thinking Corner

Which is larger: The million or the billion?

Which is larger: A part of a million or a part of a billion?

Which is more harmful: the concentration of a poisonous substance (lead, for example) in drinking water to be a part of a billion or a part of a million?

The Nano is a unique measuring unit :

From the physical and mathematical point of view, the Nano equals one part of a billion (0.000000001) of the measured unit. The nanometer (nm)equals a part of a billion part of a meter. Thus, it is 10^{-9} of a meter. There is also the nanosecond, the Nano gram, the Nano mole, the Nano joule, and so on. The Nano is used as a measuring unit for very minute particles.

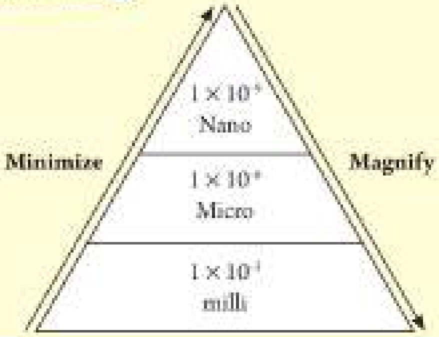
Check Your Understanding

Using 10^{n} , determine the relationship between :

ml and Micro

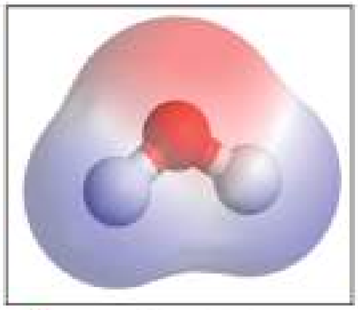
ml and Nano

Micro and Nano

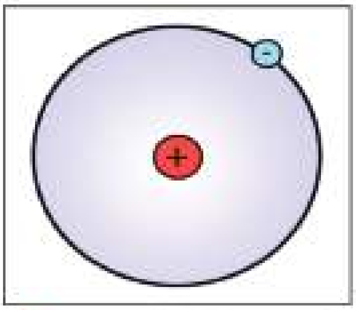


The minute nanometer can be clarified through the following examples :

▲ Figure (17) The diameter of a sand grain is about one million nanometer this equals one millimeter



▲ Figure (18) The diameter of a water molecule equals approximately 0.3nm



▲ Figure (19) The diameter of an atom is between 0.1 - 0.3 nm

What makes the Nano scale unique in its measurement, is that the properties of the substance in this dimension like color and transparency, the ability to conduct heat and electricity, the toughness and elasticity, the melting point, the speed of chemical reaction, and other properties totally change and the substance gains new and unique properties. Scientists have discovered that these properties change with the change of Nano volume properties from the substance, which is called volume dependent properties.

Critical Nano volume: the volume in which the unique Nano properties of the substance appears and is among between 1 - 100 nm.

In order for us to understand the volume dependent properties, which make the Nano substances unique, the following examples are shown:

- **Nano gold :** We know that gold is yellow-color and has a certain brightness. However, when the volume of gold decreases to become a Nano volume, if differs. Scientists have discovered that Nano gold takes different colors according to their Nano volume. So that gold maybe red, orange, green or blue since the reaction of gold with light in this dimension of the substance is different than its seen volume.

- **Nano copper :** Scientists have noticed that the toughness of copper particles increases when it shrinks from the macro measurement to the Nano measure and it differs with the difference of the Nano volume of the substance.

Figure (20) Different colors of Nano gold

Figure (21) Nano copper

What applies on the previous examples, also applies on the Nano volume for any substance. This allows the Nano substances to show super unique properties that are not shown in the volumes of the macro and micro of the substance. This leads to its usage in new and uncommon applications. The super properties of the Nano substances are due to the relationship between the surface area and the volume.

Test your Skills

Review the following drawing and calculate the ratio between the area surfaces and the volume in the three cubes. What do you infer? What happens if the division continues until we reach a cube of an angle length estimated with a nanometer?

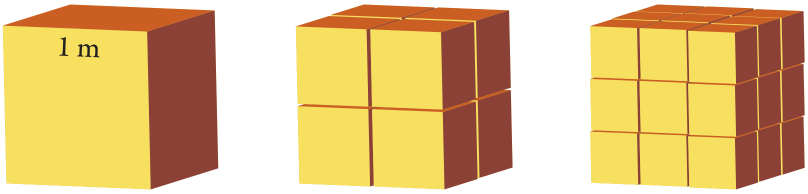


Figure (22) The relationship between surface area and volume

In the Nano volume of the substance, the ratio increases between the surface area to the volume to a very large degree. The numbers of substance atoms exposed to reactions become many if compared to their numbers in the greater volume of the substance. This ratio between the surface area to the volume acquires the Nano particles new and unique physical and chemical properties.

This may be understood if you remember that the speed of dissolving a cube of sugar in water is less than the speed of dissolving the same cube in the same amount of water, and in the same temperature if the cube is divided into small particles in the same amount of water. As the high ratio between the surface area to the volume in the case of sugar particles increases the speed of dissolving

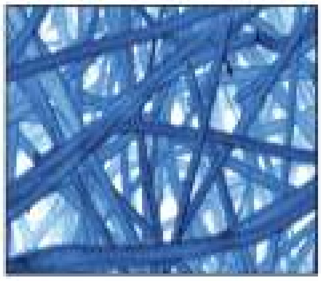
Nanochemistry

Nanochemistry is a branch of Nano science. It deals with the chemical applications of Nano substances and includes the study, description, and creating the substances with Nano dimensions. Nanochemistry also deals with the unique properties related to collecting the atoms and molecules with Nano dimensions. And as it deals with a volume of a substance that is microscopic, it has tools, technologies, and new chemical methods. Multi-form Nano substances may be in the form of particles, tubes, columns, thin films, or other forms. The Nano substances can be classified according to the number of Nano dimensions of the substance as follows:

One-dimensional Nano substances :

They are the substances that have one Nano dimension. An example of this is the thin films that are used in painting surfaces to protect them from rust and erosion. One-dimensional Nano substances are also used in packaging food products to protect them from getting spoiled or rottened. They are also used in the nanowires that are used in electrical circuits and the Nano fibers that are used in the production of water filters.

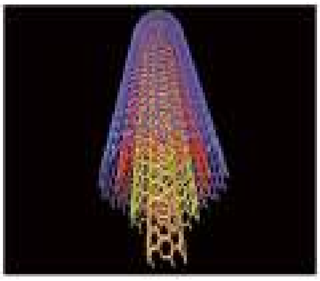
▲ Figure (23) Thin films

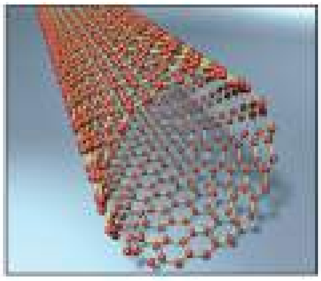


▲ Figure (24) Nano fibers

Two-dimensional Nano substances :

They are the Nano substances that have two-nanodimensions such as uni and multi carbon nanotubes.





▲ Figure (25) Uni and multi Nano tubes

The distinguished properties of carbon nanotubes include :

- A good conductor of electricity and heat. As the carbon nanotubes are a better conductor of electricity than copper. As for conducting heat, it is greater than the conduction degree of diamonds.
- It is stronger than steel due to the powerful bond between its molecules and is lighter. And therefore, the nanotubes, which equals the size of a human hair, can easily pull a truck. This power inspired scientists to think of making very strong robes that can be used in the future to create space shuttles.
- It easily connects to protein, and due to this property, it can be used as a biological sensor device as it is sensitive to certain molecules.

Three-dimensional Nano substances :

They are the substances that have three Nano dimensions like the Nano shell and the Bucky ball. The Bucky ball consists of 60 carbon atoms and is denoted by C_{60}. It has a group of special properties which depend on its structure. Notice that the molecular model of the Bucky balls appears as a hollow football. Due to this appearance, scientists test the effectiveness of using the Bucky ball as a carrier for medicine in the body. As the hollow structure can match with a molecule of a certain medicine inside it while the outer part of the Bucky balls is resist to the reaction with other molecules inside the body.

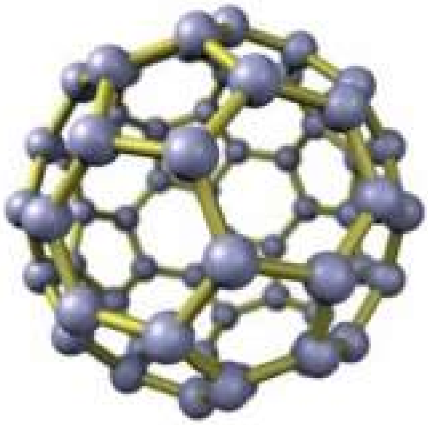


Figure (26) Bucky Ball

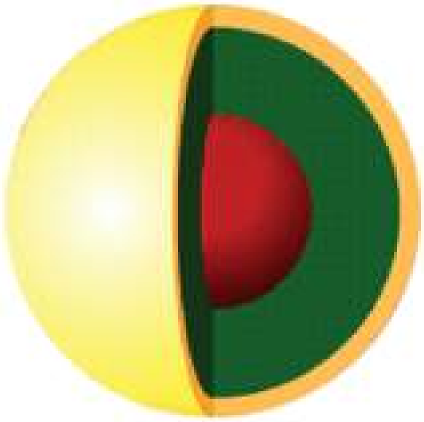


Figure (27) Nano Shell

Enrichment Information

Scientists have discovered that Damascus swords that Arabs and Muslims used long ago, and are known for their sturdiness, have in their composition silver Nano particles that give it great solidness.

Figure (28) Damascus sword

Applications on Nanotechnology

Medical Field :

- The early diagnosing of diseases and the picturing of organs and tissues.
- Precisely delivering medicine to the infected tissues and cells which increases the chances of healing and lessens the harmful side effects of traditional healing, which does not distinguish between the infected cells and the healthy cells.
- Producing very minute devices for dialysis that are implanted in the patient's body.
- Producing Nano robots that are sent into the blood stream as they remove blood clots from the vein walls without surgical interference.

Enrichment Information

Dr. Mustafa El-Sayed was the first Egyptian scientist to obtain the American National Science Pendant for his achievements in the field of nanotechnology and his application of this technology, using gold Nano compounds, to treat cancer disease.

Agricultural Field :

- Identifying bacteria in nutrients and preserving food.
- Improving nutrients, pesticides, and medicine for plants and animals with special features.

Energy Field :

- Producing solar cells using Nano silicon that is distinguished by a high transformation capability of energy and non-leakage heat energy.
- Producing hydrogen fuel cells that are low on cost and high on performance.

Industrial Field :

- Producing invisible Nano molecules that acquire glass and ceramics the property of self-cleaning.
- Producing Nano substances to purify ultraviolet rays in order to improve sunblock cosmetics and creams.
- Producing a Nano wrapping technology in the form of paints and sprays that work to form layers of coverings that protect the screens of electrical devices from scratching.
- Producing repellent tissues for stains that are distinguished with self-cleaning.

Communications Field :

- Producing wireless Nano devices, mobiles, and satellites.
- Decreasing the size of the transistor.
- Producing electric chips that are distinguished with a high storage capability.

Environmental field :

- Producing Nano filters that work ion purifying the air and water, solving the problem of nuclear wastes, and eliminating the dangerous elements from industrial wastes.

Go Further

For more knowledge about this topic you can refer to the Egyptian Knowledge Bank (EKB) through the opposite link.

The possible harmful effects of nanotechnology

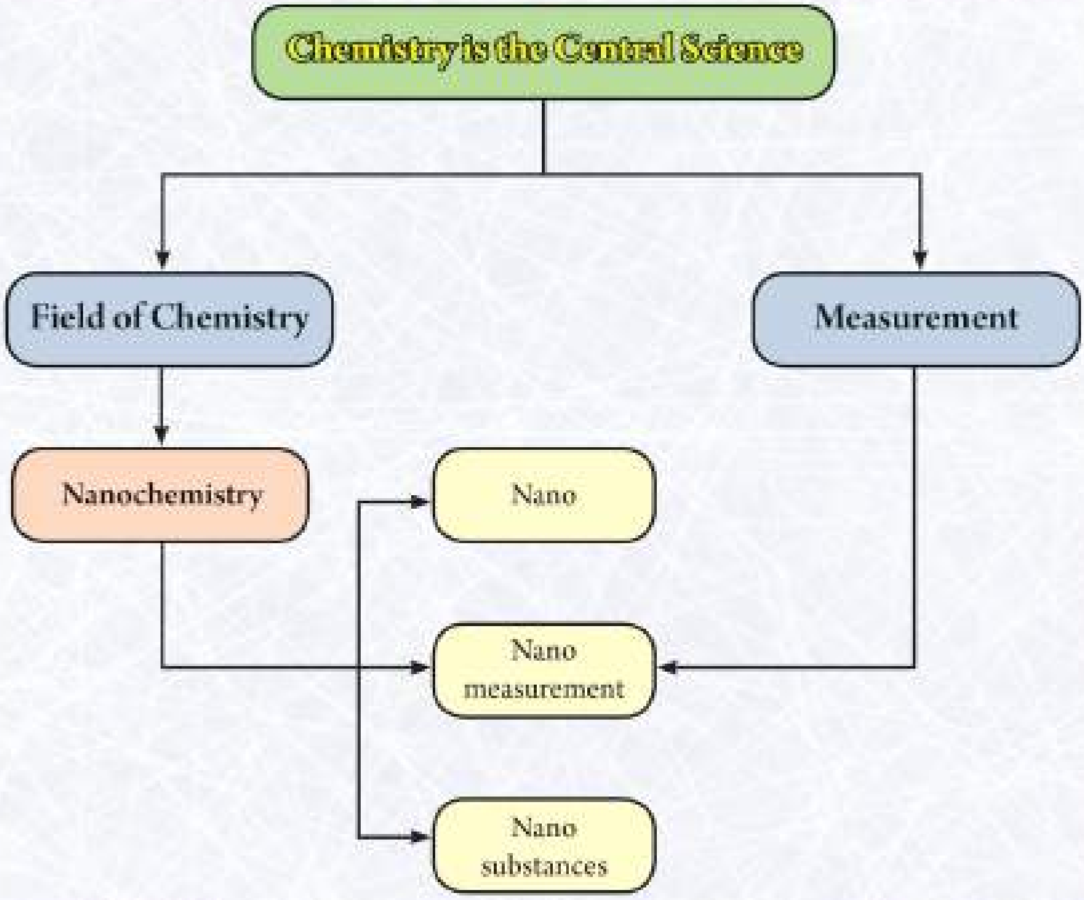
Although the technology of Nano has various applications, some people believe that there could be harmful side effects from this technology. Their fears are summarized as follows:

- Medical effects: is represented the very minute Nano particles that may slither from the cell membranes of the skin and lungs to yield inside the human body or inside the bodies of animals and the cells plants. Thus, negatively affecting the health of all these organisms.
- Environmental effects: it includes the Nano pollution, which are wastes resulting from the process of producing Nano substances. As they may be quite dangerous due to its size as they may be suspended in the air and thus, may easily penetrate the animal and plant cells. Nano pollution may also have its negative effects on the atmosphere, water, air, and soil.
- Social effects: Specialists associated with the social effects of the Nano technology believe that it will add to the problems resulting from social and economic inequality that already exists and includes, but not limited to, the uneven distribution of technology and resources.

Basic Terminology in Unit One

- **Chemistry:** the science that is interested in the study the substance composition, its properties, changes that occur to it, the reactions of different substances with each other, and the appropriate circumstances for this.
- **Measurement:** the comparison of an unknown amount with another amount of its kind to know the number of times the first includes on the second.
- **Measurement unit:** It is a certain portion of a certain physical amount, which is known and authorized by law.
- **Nanotechnology:** the technology of very minute substances, and it specializes in treating the substance on the Nano measure to produce new, useful, and unique resultants in its properties.
- **Nanochemistry:** is a branch of Nano science. It deals with the chemical applications of Nano substances.

Organizational Chart of Unit One



Lesson One : Chemistry and Measurement

Application Activity : Relationship Between Chemistry and Biology (Harmfulness of drinking tea after food)

Security and Safety

Purpose of the Activity

☑ Conclude the relationship between chemistry and other sciences.

☑ Explain the danger of drinking tea immediately after eating.

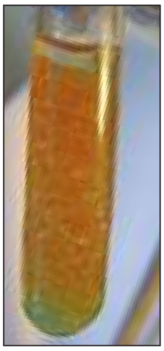
Acquired Skills

☑ Hypotheses – Experimentation – Conclusion

Materials

☑ Cup of tea – lemon juice or vitamin C – iron sulfate III salt – test tubes – tube carrier – 2 glass flasks of 100 ml

Solution



Precipitant

Procedure :

With your classmates, follow the steps of the scientific method to answer the problem in this activity.

- Dissolve 3 g of iron III sulfate in 50 ml of distilled water. Take the purifier from the solution in a test tube and record its color.

  Color: ....

- Spill a small amount of tea in a test tube, and then spill an amount of iron III sulfate on it. Record your observations.

  Observation: ....

- Dissolve vitamin C or drops of lemon juice in distilled water.
- Add drops of the lemon juice solution or vitamin C to the precipitant formed. Record your results. Does the color of the precipitant refer to the iron III sulfate solution?

  Observation: ....

Conclusion and explanation :

- What do you conclude from this experiment?

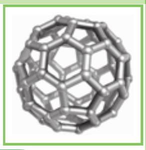
  ....

- Clarify how we can make use of the results of this experiment in our everyday life.

  ....

- From the previous experiment, explain how chemistry contributes in biology.

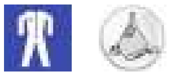
  ....



Unit 1
Activities and Assessment Questions

Application Activity : Using Measurement Tools (Determining Water Density)

Security and Safety



Purpose of the Activity

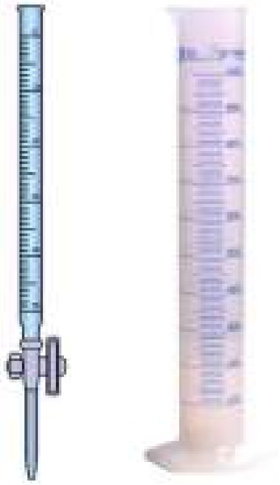
☑ Using the measuring tools with accuracy.

Acquired Skills

☑ Using the tools – observation.

Materials

☑ 100 ml glass cup filled with distilled water – graduated cylinder – pipette – digital balance – burette – plastic bottle.



Procedure :

First : Determining distilled water's density by using a graduated cylinder

- Using the balance, determine the mass of the cylinder.
- Using a straw, fill the graduated cylinder up to 10 ml with the distilled water found in the flask.
- Identify the mass of the graduated cylinder that has water by using the balance.
- Using the date that you have, identify the mass of the water.

Recording data :

Mass of empty cylinder	Mass of cylinder with water	Water mass	Water volume	Water density
....	....	....	....	....

Second : Identifying Water Mass by Using a Burette

- Using the balance, determine the mass of a small and empty plastic bottle.
- Fill a 50 ml burette with distilled water in room temperature from the flask.
- Record the reading of the burette from the beginning.
- From the burette, add 5 ml of distilled water to the plastic bottle.
- Record the final reading of the burette and determine the water volume inside the plastic bottle.
- Identify the mass of the bottle with water by using the balance.
- Using the data you have, determine the water density.

Recording data :

Mass of empty plastic bottle (g)	Mass of bottle with water (g)	Water mass (g)	Water volume (ml)	Water density (g/ml)
....	....	....	....	....

Analyze :

- Compare between the density of water in each of the two previous experiments

  ....

- Identify the sources of possible errors in the previous measurements.

  ....

- Which of the results are more accurate and why?

  ....

Assessment Questions

First : Choose the correct answer :

1. One of the following is used to determine the mass of substances ....

A. Burette B. Pipette

C. Sensitive balance D. Round bottom flask

2. One of the types of glass tools used in the operations of preparation and distillation ....

A. Burette B. Pipette

C. Sensitive balance D. Round flasks

3. The pH value of acidic solution is ....

A. > 7 B. < 7

C. $= 7$ D. $= 14$

4. Which of the following is used in the titration ....

A. Round bottom flask B. Conical flask

C. Pipette D. Graduated cylinder

Second : Justify :

1. Measurement has great importance in chemistry.

....

2. Chemistry is considered the center for most other sciences as biology, physics, and agriculture.

....

3. The measurement of pH has a great degree of importance in chemical and biochemical reactions.

....

Third : Write the scientific terminology :

1. Systematic knowledge that includes facts, concepts, principles, laws, and theories that are coordinated in an assortment or structure ....
2. The science that is interested in the study the substance composition, its properties, changes that occur to it, the reactions of different substances with each other, and the appropriate circumstances for this ....
3. The comparison of an unknown amount with another amount of its kind to know the number of times the first includes on the second ....
4. Long glass tube opened from both sides and its graduation starts from top to bottom ....
5. A device used to measure the mass of matter ....

Fourth : Various questions :

1. Observe the figure in front of you and then answer :

   A. Write the names of the tools 1 and 2.

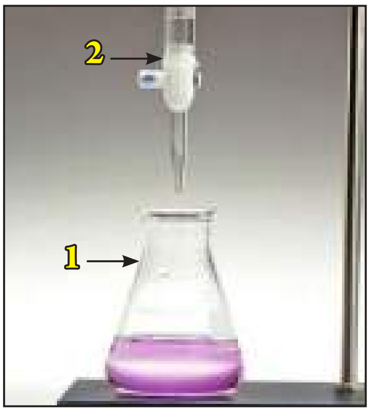
   ....

   ....

   B. Write one function for each of them.

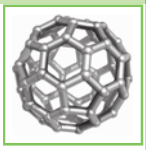
   ....

   ....



2. Determine the appropriate tools for the following usages :

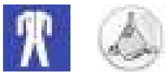
Tool	Use
A.	Determine the volume of liquids and the irregular solid objects
B.	Transport a certain amount of a matter
C.	Add accurate volumes of liquids during degradation
D.	Prepare solutions of known concentrations with accuracy



Lesson Two : Nanotechnology and Chemistry

Application Activity : Identify the Nano Scale

Security and Safety



Purpose of the Activity

- ☑ Conclude the relationships between the different dimensions.
- ☑ Identify the Nano scale.
- ☑ Using the pH (10^n) to express the Nano.

Acquired Skills

- ☑ Measurement – observation – conclusion.

Materials

- ☑ White paper – food pigment – dropper – 200 ml of water – cup of water – 9 small cups – pipette (10 ml) – dye

The following table shows the different abbreviated suffixes used to express length. Understand these units and then use the schedule to find the relationships between the following lengths:

Suffix	Measurement	Scientific notation
Kilo	1000 m	1×10^3 m
Meter	1 m	1×10^0 m
Deci	0.1 m	1×10^{-1} m
Centi	0.01 m	1×10^{-2} m
Milli	0.001 m	1×10^{-3} m
Micro	0.000001 m	1×10^{-6} m
Nano	0.000000001 m	1×10^{-9} m

First measuring unit	Second measuring unit	Relationship
Kilometer	Meter	10^3 m
Meter	Micrometer	A. ....
Micro	Nano	B. ....
Meter	Nano	C. ....

Cooperate with your classmates in solving the following problem:

✪ When adding a colored substance to water, in which concentration does the solution appear without color? ....

Procedures :

- Number the cups with the numbers from 1-9. Place a white paper under the cups.

....

- Using the pipette , place 1 ml from the food pigment and 9 ml of water in the cup number 1. Gently move the cup to mix the solution.

....

- In cup number 2 , use the pipette to transport 1 ml of the solution of cup number 1 and then add 9 ml of water.

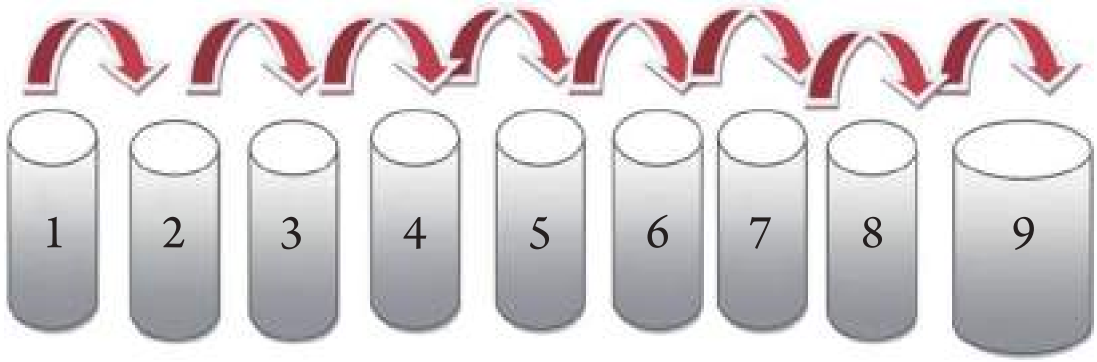
....

- Continue the dilution process as you have done above until you reach cup number 9.

....

- In the results table, describe the color of the solution and the concentration in each case.

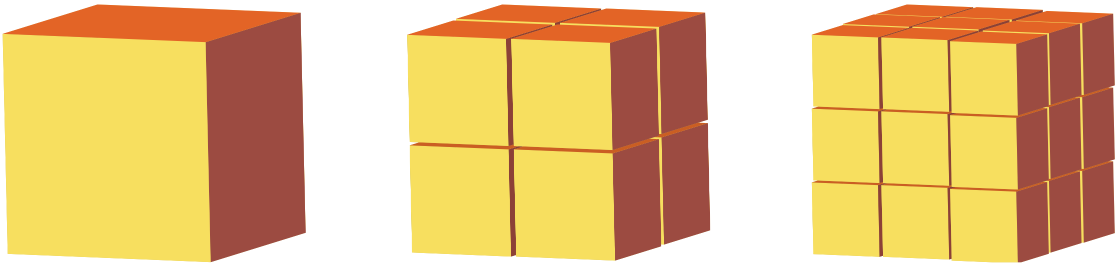
....



Cup number	1	2	3	4	5	6	7	8	9
Concentration	....	....	....	....	....	....	....	....	....
Color of solution	....	....	....	....	....	....	....	....	....

Assessment Questions

1. You have a cube with a side length of 1 cm . It has been divided into sequentially smaller squares. Use the following table to express the relationship between the volume of the cube and the surface area in each case.



Side length of a cube – cm	Number of cubes	Area of one of the faces – cm^2	Sum areas of the six faces of the cube – cm^2	Total surface area – cm^2	Volume – cm^3	The ratio between area and volume
1	1	....	....	....	....	....
0.50	8	....	....	....	....	....
0.25	....	....	....	....	....	....
....	....	....	....	....	....	....

A. If the division of the cube continues to reach a Nano volume of a matter, which of the following expressions are correct?

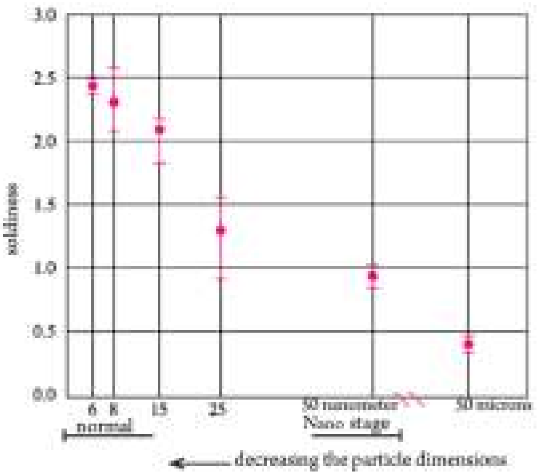
First: the ratio between the surface area and volume increases and the speed of the chemical reaction increases.

Second: the ratio between the surface area and volume decreases and the speed of the chemical reaction decreases.

B. Explain your answer in light of the number of atoms subjected to the reaction.

....

2. The following figure expresses the relationship between the volume of the copper particles and its solidness. Notice the figure and answer the following questions:



A. What is the volume in which the solidness of the copper particles is of lesser value? ....

B. How does the solidness of the particles change by its shrinkage to the Nano size?

....

C. What is the volume in which the solidness of copper particles is of higher value? ....

D. How does the solidness of the particles change with the change of the Nano size?

....

3. The figure in front of you shows a drop of ink on a piece of cloth:

A. Explain the phenomenon.

....

....

B. What is its relationship with Nano technology?

....

....

C. Which daily life appearances are related with this phenomenon?

....

D. How has this phenomenon been useful in every day life applications?

....

Unit One Revision Questions

First : Choose the correct answer :

1. Specializes in the study of the chemical composition of the cell parts ....
   A. Physical chemistry B. Biochemistry
   C. Organic chemistry D. Electrochemistry

2. One of the 1D Nano substances ....
   A. Nano fibers B. Nano tubes
   C. Nano shell D. Bookie balls

3. Which of the following expresses the Nanometer? ....
   A. 1×10^{9} Meter B. 1×10 Meter
   C. 1×10^{-9} Meter D. 1×10^{-3} Meter

4. The Nanometer is important in our life because ....
   A. It needs special tools to see it and deal with it.
   B. It shows new properties that have not appeared before.
   C. It needs special methods to manufacture it.
   D. All the choices above.

5. Small volumes of liquids can be measured by a ....
   A. Graduated beaker B. Graduated cylinder
   C. Measuring flask D. Test tube

6. Which of the following amounts is larger? ....
   A. 10^{-6} B. 10^{-9}
   C. 10^{-3} D. 10^{-2}

7. When dividing a cube into smaller cubes ....

A. The surface area decreases and the volume decreases.

B. The surface area increases and the volume decreases.

C. The surface area decreases and the volume remains fixed.

D. The surface area increases and the volume remains fixed.

8. The behavior of Nano particles is related with its very small size because ....

A. The ratio between the surface area to the size is very large in comparison with the larger size of the matter.

B. The number of atoms on the surface of the particles is large in comparison to their numbers to the larger size of the matter.

C. The number of atoms on the surface of the particles is small in comparison to their numbers the larger size of the matter.

D. A and B are true answers.

Second : Write the scientific terminology :

1. Deals with the treatment of the matter on the Nano scale to produce new useful products. ....

2. A branch of the Nano science that deals with the chemical applications of the Nano substances. ....

3. Used to state the volumes of liquids and the irregular solid bodies. ....

4. Changes the properties of the Nano particles of different sizes in the range of the Nano scale. ....

5. Includes the study, description, and production of the substances with Nano dimensions. ....

6. Equals one of a billion of a meter. ....

Third : Choose from the column (A) what is appropriate from column (B), and then choose what is appropriate from column (C) :

Column (A)	Column (B)	Column (C)
Substances that have one Nano dimension	Nano shells	Space shuttles
Substances that have two Nano dimensions	Nano wires	Treatment of cancer
Substances that have three Nano dimensions	Nano carbon tubes	Electronic circuits

Fourth : Compare between the following :

1. Normal solar cells and Nano solar cells.
2. Solidness of copper and the Nano particles of copper.

Fifth : Write a short answer about :

1. The harmful and beneficial health effects of the Nano technology.

....

2. The importance of the relationship between the surface area and the size in Nano substances.

....

Sixth : What is meant by each :

1. Measurement.

....

2. Measuring unit.

....

3. Nanotechnology.

....

General objectives of unit two :

By the end of this unit, the student will be able to :

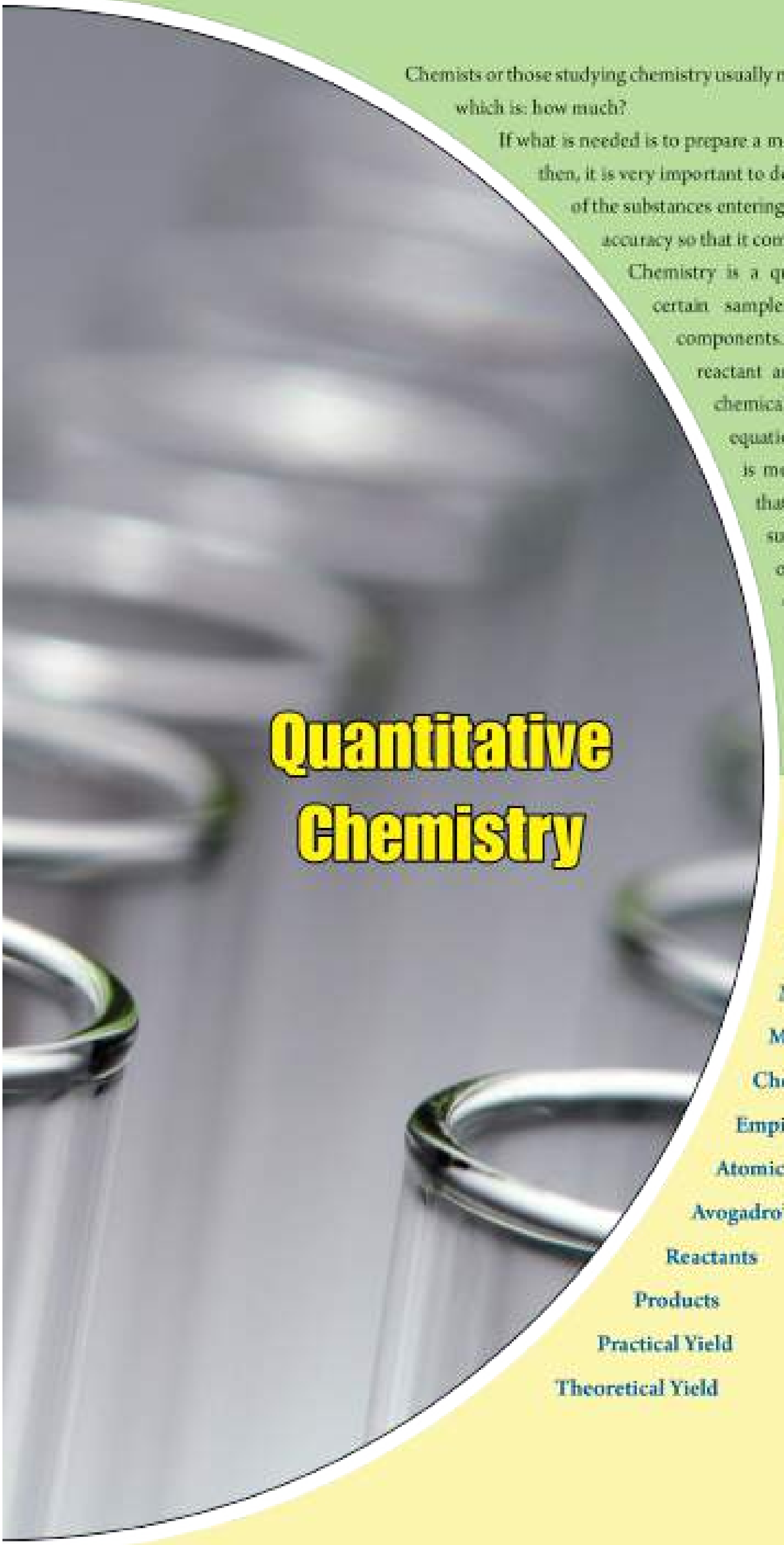
- Express a chemical reaction using a balanced symbolical equation.
- Calculate the mass of the mole of a chemical compound by using of the atomic mass.
- Mention the relationship between the mole and the Avogadro's number.
- Identify the molar volume of gas at (STP).
- Calculate the number of moles of gas by using its volume and molar volume.
- Calculate the weight percentage of the components of a substance by using its chemical formula or with the experimental results.
- Deduce an empirical formula and a molecular formula of the compound by using the experimental results.
- Calculate the amounts of reactants and products in the balanced chemical equation.

Unit Two lessons :

(1) The Mole and the Chemical Equation

(2) Calculation of the Chemical Formula

Involved Issues : Consumption Rationalization



Quantitative Chemistry

Chemists or those studying chemistry usually need to answer an important question, which is: how much?

If what is needed is to prepare a medical drug using a chemical method then, it is very important to determine the amount and ingredients of the substances entering in the composition of this drug with accuracy so that it comes with the anticipated results.

Chemistry is a quantitative science used to analyze certain samples to identify the ratio of their components. Therefore, the specification of the reactant amounts and the products from the chemical reaction is related with the chemical equation expressing this reaction. There is more than one method for measuring that can be dealt with the different substances like the mass or the number or the size. This depends on the nature of the substances that we deal with. In this chapter, we will deal with the calculative methods used to identify the amounts of chemical reactions.

Key Terms :

- Balanced Equation
- Mass
- Mole
- Molecular Formula
- Chemical Formula
- Empirical Formula
- Atomic Mass
- Avogadro's Number
- Reactants
- Products
- Practical Yield
- Theoretical Yield

Lesson One : The Mole and the Chemical Equation

Learning Outcomes

By the end of this lesson, you will be able to:

- ✓ Express a chemical reaction using a balanced symbolical equation.
- ✓ Calculate the mass of the mole of a chemical compound in terms of the atomic mass.
- ✓ Mention the relationship between the mole and the Avogadro number.
- ✓ Identify the size of the mole gas at (STP).
- ✓ Calculate the number of gas moles in terms of its size and the size of one mole.
- ✓ Calculate the amounts of reactant substances that results from the balanced equation using the units of mole and mass.
- ✓ Appreciate the efforts of scientists.
- ✓ Appreciate the ingenuity of the Creator and His creativity in the universe.

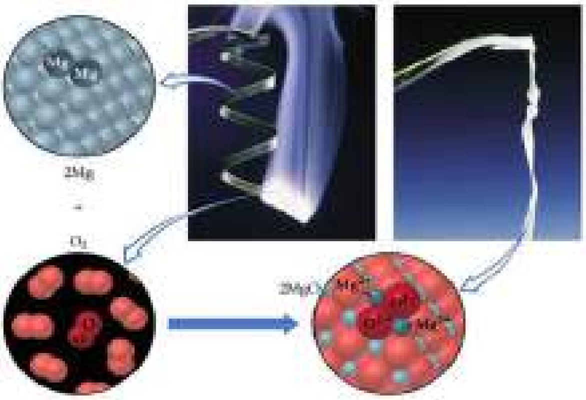
Chemical Equation

The next link in EKB explains how do you balance the chemical equation.

Table (1) shows the symbols used to express the physical states and is written at the bottom left of the chemical symbol of the substance.

Solid	s
Liquid	ℓ
Gas	g
Aqueous Solution	aq

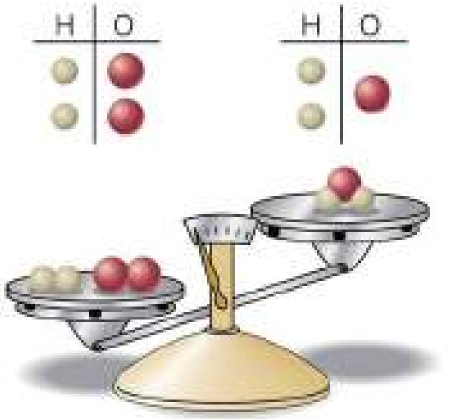
▲ Table (1) Symbols of the physical state ot the substance



Burning of magnesium in oxygen

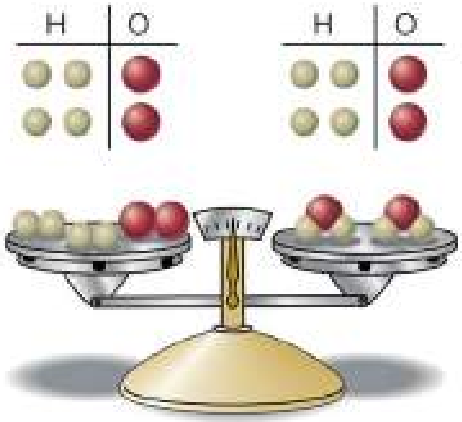
- The chemical equation must be balanced. In other words, the number of atoms of the reactant's element is equal to the number of atoms of the same element resulting from the reaction to achieve the law of mass conservation. The following equation expresses the reaction of the combination of hydrogen with oxygen to form water. By looking at the equation in figure (1), we find that the number of the resultant oxygen atoms from the reaction is less than those entering in the reaction. In order to balance the equation, we start to deal with it as a mathematical equation by multiplying the two sides of the equation in a factore that make the equation balanced as follows:

$H_2 + O_2 \longrightarrow H_2O$



▲ **Figure (1) Before balancing the equation**

$2H_2 + O_2 \longrightarrow 2H_2O$



▲ **Figure (2) After balancing the equation**

- The chemical equation represents a law for the quantitative relationships between the reactants and the products, i.e. these quantities can be doubled or divided.

Ionic Equation :

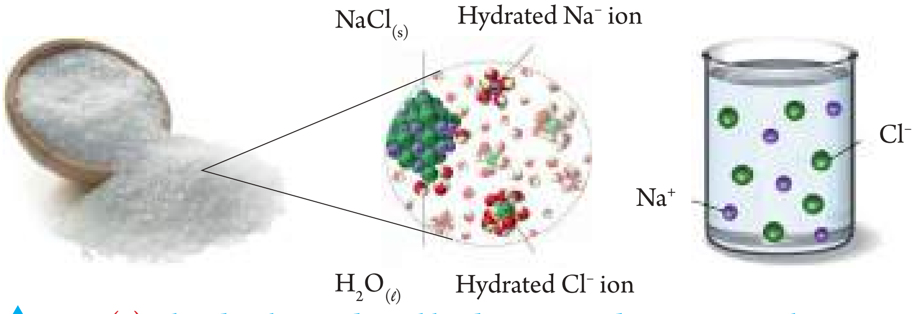
- Some physical operations like dissociating of some ionic compounds when dissolved in water or melting. There are also chemical reactions occurring between the ions like the equilibrium reactions between the acid and the base and the precipitation reactions that are expressed in the form of ionic equations.

✓ When dissolving sodium chloride in water, it is expressed by the following ionic equation:

$$NaCl_{(s)} \xrightarrow{\text{water}} Na^{+}_{(aq)} + Cl^{-}_{(aq)}$$

1 mol 1 mol 1 mol

This means that a mole of NaCl produces a mole from Na^+ ions consisting of 6.02×10^{23} Na^+ ion and mole from Cl^- ions consists of 6.02×10^{23} Cl^- ion. The total sum of the number of ions in the solution is 12.04×10^{23} ion.



▲ **Figure (9) When dissolving sodium chloride in water, it dissociates into Cl^-, Na^+ ions**

✓ Neutralization of sulfuric acid with sodium hydroxide to form sodium sulfate salt and water can be expressed with the following symbolic equation:

$$2NaOH_{(aq)} + H_2SO_{4(aq)} \longrightarrow Na_2SO_{4(aq)} + 2H_2O_{(\ell)}$$

As these substances are in their aquatic solutions, they are found in the form of ions except water, which is the only substance, found in the form of molecules, this reaction can be expressed in the form of an ionic equation as follows:

$$\cancel{2Na^{+}}_{(aq)} + 2OH^{-}_{(aq)} + 2H^{+}_{(aq)} + \cancel{SO^{2-}_{4}} \longrightarrow \cancel{2Na^{+}}_{(aq)} + \cancel{SO^{2-}_{4}} + 2H_2O_{(\ell)}$$

By looking at the previous equation, we find that the Na^+ ions and the $SO^{2-}_{4(aq)}$ ions remained free in the reaction, it did not participate in the reaction. By neglecting it from the two ends of the equation, we get the ionic equation of the reaction, which shows the reactant ions only.

$$2OH^{-}_{(aq)} + 2H^{+}_{(aq)} \longrightarrow 2H_2O_{(\ell)}$$

When adding drops of potassium dichromate solution into silver nitrates solution, silver chromate forms. It does not dissolve in water and separates in a solid, red, precipitant form.

$$K_2Cr_2O_{7(aq)} + 2AgNO_{3(aq)} \longrightarrow 2KNO_{3(aq)} + Ag_2Cr_2O_7\downarrow_{(s)}$$

Test your Skills

Express the previous reaction with a balanced ionic equation.

Notice

In the balanced ionic equation, the sum of the positive charges have to be equal to the sum of the negative charges in each of the two sides of the equation, in addition to the equal number of atoms of elements intered and produced from the reaction.

Remember

Molecule: the smallest part of a substance that can be found in a single state. The properties of the substance are evident in it.

Atom: the smallest building unit of the substance that participated in chemical reactions.

Both the molecule and the atom are all very small particles in which their dimensions are estimated by a nanometer unit and are difficult to practically deal with.

The Mole

Scientists have agreed on using the term "Mole" in the International System of Units (S.I) to express the amounts of substances used and resultant from the chemical reaction.

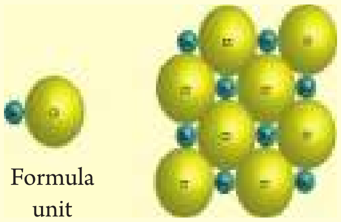
The next link in EKB shows how can you calculate the molcular mass and molar mass.

From the previous link calculate the mass of CO_2 gas.

- In the case of ionic compounds, in which the building units can be expressed by the formula unit instead of the molecule, the formula unit mass can be calculated in the same manner as the molecular mass calculation.

Notice

The ionic compounds are in the form of a regular geometrical structure known as the crystal lattice as the ion is surrounded with opposing ions, in terms of charge, from all directions. This can be expressed by the formula unit that clarifies the ratio between the ions composing it. The image in front of you shows an organizational chart of the crystal lattice of the ionic sodium chloride salt.



Formula unit

Crystal lattice

For example, the formula unit mass from the ionic calcium chloride $CaCl_2$ is calculated as follows:

Mass of $CaCl_2$ = (2 × chloride ion mass) + (1 × calcium ion mass)

If you know, that the chlorine's atomic mass = 35.5 and the calcium's atomic mass = 40

Then the mass of $CaCl_2$ = (2 × 35.5) + (1 × 40) = 71 + 40 = 111 a.m.u.

And thus a mole of $CaCl_2$ = 111 grams

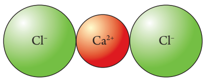


Figure (3) Calcium chloride formula unit

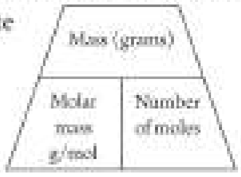
Enrichment Information

The first scientist who named the "mole" was the scientist, Wilhelm Ostwald, in 1894 and was originated from the German word "Mol". It is derived from the word "Molecule".

If you use a mass of carbon dioxide with an amount of 44 g, this means that you use one mole of it. If you use another mass of it with an amount of 22 g, then you are using half a mole of it.

$$\text{Number of moles from the substance} = \frac{\text{Mass of substance (gram)}}{\text{Mass of one mole of it (g.mol}^{-1}\text{)}}$$

- The mass of a mole (molar mass) differs from one matter to another. This is due to the difference in matters in their molecular composition and therefore, the difference in their molecular mass. As a mole of copper (Cu) = 63.5 g while a mole of hydrated copper sulphate ($CuSO_4.5H_2O$) = 249.5 g



- The mole of the molecules of an element differs from the mole of the atoms of the same element in the elements with diatomic molecule like oxygen O_2, nitrogen N_2, hydrogen H_2, and others.

If the oxygen is in the form of molecules, then the molar mass from the oxygen molecules is 32g = 16 × 2 = O_2.

If the oxygen is in the form of atoms, then the molar mass from the oxygen atoms is 16 g = 16 × 1 = O.

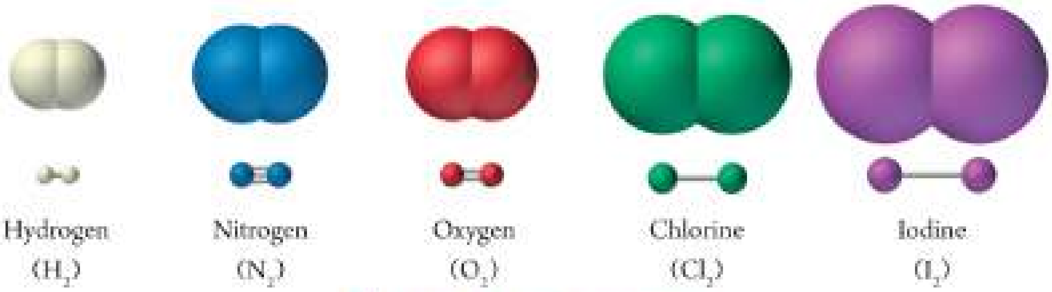


Figure (5) Bi-atom molecules

- There are elements with different molecular compositions due to their physical state like

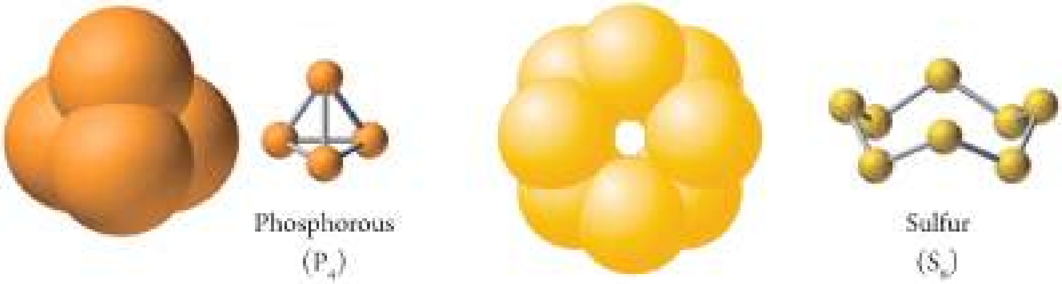


Figure (6) Different molecular composition according to the physical state

Test your Skills

Calculate the molar mass of P_4, NaCl, H_2SO_4, H_2O knowing that the atomic masses are [H = 1, O = 16, S = 32, Cl = 35.5, P = 31]

We can calculate the amounts of reactants and products in the reaction between magnesium and oxygen reaction as follows:

$$2Mg_{(s)} + O_{2(g)} \xrightarrow{\Delta} 2MgO_{(s)}$$

2 moles of magnesium need 1 mole of oxygen to produce 2 moles of magnesium oxide, i.e. 48 grams of magnesium need 32 grams of oxygen to produce 80 grams of magnesium oxide; knowing that the atomic mass for magnesium and oxygen is 16 a m u and 24 a m u.

$2Mg$	+	O_2	$\longrightarrow$	$2MgO$
2 mol		1 mol		2 mol
2×24		2×16		$2(24 + 16)$
48		32		2×40
	80 g			80 g

▲ Figure (7) The relationship between the amounts of reactants and the products in the reaction between magnesium and oxygen.

Determing the limiting reactant in the reaction :

Every chemical reaction needs accurately calculated amounts of reactants to obtain the required amounts of products. if the amount of a reactant increases more than required, this access amount remains as it is without participating in the reaction. the reactant material consumed totally during the chemical reaction is called the determining material of the reaction, which resulted from its reaction with other reactants the least number of moles of the products.

Example:

Magnsium reacts with oxygen according to the equation: $2Mg_{(s)} + O_{2(g)} \longrightarrow 2MgO_{(s)}$

What is the determining factor of the reaction as using 32g of oxygen with 12 g of magnsium?

[Mg = 24 and O = 16]

Solution:

Number of moles of $O_2 = \frac{32}{32} = 1$ mol

Number of moles of MgO = 1 mol $O_2 \times \frac{2 \text{ mol MgO}}{1 \text{ mol } O_2}$ = 2 mol MgO

Number of moles of Mg = $\frac{12}{24} = 0.5$ mol

Number of moles of MgO = 0.5 mol Mg $\times \frac{2 \text{ mol MgO}}{2 \text{ mol Mg}}$ = 0.5 mol MgO

∴ Magnsium is the determining factor of the reaction because the number of moles of MgO resulted from it is lesser in number.

The Mole and Avogadro's number

The next link in EKB explain the relation between the mole and Avogadro's number:

From the previous link in EKB, we can express the relationship between the number of moles and the number of atoms, molecules or ions in the overall law:

Number (Atoms or Molecules or Ions) = Number of moles (Atoms or Molecules or Ions) × Avogadro's number (6.02×10^{23})

Example:

Calculate the number of carbon atoms found in 50 g of calcium carbonates, knowing that:

[Ca = 40 , C = 12 , O = 16]

Solution:

Mole of calcium carbonates $CaCO_3$ = 16 × 3 + 12 + 40 = 100 g

As one mole of $CaCO_3$ $\xrightarrow{\text{contains}}$ 1 mol of carbon atoms (C)

i.e. 100 g $\xrightarrow{\text{contains}}$ 1 mol of carbon atoms (C)

therefore, 50 g $\xrightarrow{\text{contains}}$ X mol

$\therefore$ X (Number of carbon atom moles) = $\frac{1 \times 50}{100}$ = 0.5 mol

$\therefore$ Number of carbon atoms = $0.5 \times 6.02 \times 10^{23} \times 0.5 = 3.01 \times 10^{23}$ atom

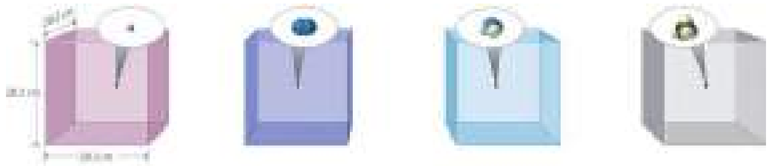
The Mole and the Volume of Gas

It is known that the solid or liquid matter has a definite and constant volume. It can be measured by various methods. As for the volume of gas, it is always equal to the volume of the space or container it occupies. However, due to research and experimentation, that the mole, from any gas, if placed in the standard temperature and pressure (STP), it occupies a certain volume estimated to be 22.4 liters.

Notice

The standard temperature and pressure (STP) means the existence of the matter in a temperature of 273 K, which equals 0°C and a pressure of 760 mm.Hg which is the normal atmospheric pressure 1 atm.p

This means that a mole of methane gas CH_4 occupies a volume of 22.4 liters and a mole of ammonia gas NH_3 also occupies a volume of 22.4 liters in condition that these gases are in the STP.



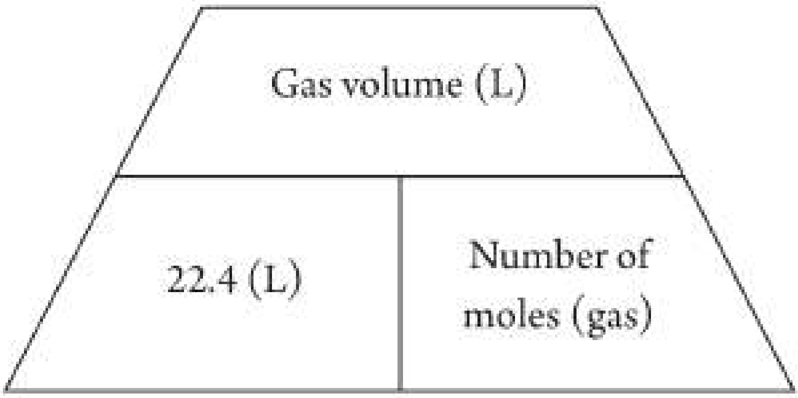
He	N_2	NH_3	CH_4
4 g	28 g	17 g	16 g
n = 1 mol	n = 1 mol	n = 1 mol	n = 1 mol
V = 22.4 L	V = 22.4 L	V = 22.4 L	V = 22.4 L

Figure (10) The relationship between the numberof moles of gas and its volume in STP

Avogadro's law: gas volume is directly proportional to the number of its moles when the temperature and pressure are constant.

And therefore, the relationship between the number of gas moles of gas and its volume at the standard temperature and pressure (STP) can be expressed as follows:

Volume of gas (STP) = number of moles × 22.4 L



Example:

Calculate the volume of oxygen needed to produce 90 g of water by reacting with an excess amount of hydrogen at the standard temperature and pressure (STP). [O = 16 , H = 1]

Solution:

$$2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(\ell)}$$

2 mol   1 mol   2 mol

Molar mass of water $H_2O = 16 + 1 \times 2 = 18$ g

From the equation , we find that :

1 mol of $O_2 \longrightarrow$ 2 mol of H_2O

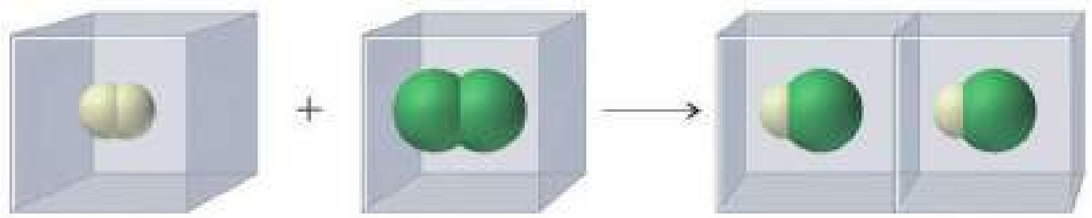
X mol of $O_2 \longrightarrow$ 90 g of H_2O

$\therefore$ X (Number of oxygen's moles) $= \frac{1 \times 90}{36} = 2.5$ mol

$\therefore$ Volume of oxygen gas $= 22.4 \times 2.5 = 56$ L

Avogadro's hypothysis: equal volumes of different gases contain the same number of molecules under the same standard temperature and pressure.

This means that the mole from any gas at the standard temperature and pressure (STP) occupies a volume of 22.4 liters and contains 6.02×10^{23} molecules from this gas. If the number of moles doubles, the volume doubles, and the molecules also double.



Hydrogen (H_2)	Chlorine (Cl_2)	Hydrogen chloride (2HCl)
1 mol	1 mol	2 mol
22.4 L	22.4 L	2×22.4 L
6.02×10^{23} molecule	6.02×10^{23} molecule	$2 \times 6.02 \times 10^{23}$ molecule

▲ **Figure (11) The volumes of introducing and producing gases are of fixed ratios**

From the previous, we can conclude a number of concepts for the mole which include:

- The atomic, molecular, ionic or formula units are expressed in grams.
- A constant number of molecules, atoms, ions or formula units estimated by 6.02×10^{23}.
- Volume of 22.4 L of gas at the standard temperature and pressure (STP).

> The mole: the quantity of matter that contains Avogadro's number (6.02×10^{23}) of atoms, molecules, ions or formula units of the substance.

Lesson Two : Calculation of Chemical Formula

Learning Outcomes

By the end of this chapter, you will be able to:

- ✓ Calculate the percentage of the components of a matter by using its chemical formula or by using the experimental results.
- ✓ Infer the empirical formula and the molecular formula of the compound by using the experimental results.
- ✓ Calculate the percentage of the actual product with respect to the calculated theoretical product from the balanced chemical equation.

Mass Percentage

The stickers found on food cans or mineral water, and the instructions found in medicine boxes are all necessary to guide the consumers of the compositions of these products. The term weight percentage is usually used which means the number of units from the particle for each 100 units from the overall. In chemical calculations, we use the word "weight percentage" to calculate the ratio of each component from the components of a certain sample. When calculating the weight percentage of nitrogen in the fertilizer of ammonium nitrates NH_4NO_3, we must know how many grams of nitrogen is found in 100 g of fertilizer. This can be calculated with the assistance of the molecular formula of the material or through the experimental results that are practically obtained.

$$\text{Mass percentage} = \frac{\text{Element mass in the sample}}{\text{Total mass of the sample}} \times 100$$

Add to your Information

The weight percentage of an element in a compound can be calculated from of the atomic mass of the element and the molar mass of the compound from the relation:

$$\frac{\text{Mass of the element in one mole of the compound}}{\text{Molar mass of the compound}} \times 100$$

The molar mass of ammonium nitrate NH_4NO_3 = (O) × 3 + (N) × 2 + (H) × 4

= 16 × 3 + 14 × 2 + 1 × 4 = 80 g

This mass contains inside it 2(N) 14 × 2 = 28 g of nitrogen

$$N\ \% = \frac{\text{Mass of nitrogen (28)}}{\text{Mass of ammonia (80)}} \times 100 = 35\ \%$$

Calculate the percentage of both oxygen and hydrogen using the same method.

The sum of the weight percentages of the elements forming the compound must be equal to 100. In the ammonium nitrites, we find that the nitrogen weight percentage (35%) + oxygen percentage (60%) + hydrogen weight percentage (5%) = 100%.

Notice

The weight percentage of an element in a compound can be calculated from of its weight percentage in this compound.

The number of moles of each element in a compound can be calculated from its percentage and the molar mass of the compound.

Example:

Calculate the number of moles of carbon in an organic compound containing only carbon and hydrogen. If you knew that the weight percentage of carbon in this compound is 85.71 % and the molar mass of this compound is 28 g (C = 12 , H = 1).

Solution:

$$\text{Carbon mass} = \frac{\text{Carbon's weight percentage} \times \text{Molar mass of the compound}}{100} = \frac{85.71 \times 28}{100} = 24\ g$$

$$\therefore \text{ Number of carbon moles} = \frac{24}{12} = 2\ mol$$

Calculation of Chemical Formula

The chemical formulas are divided into a number of types that include the empirical formula, the molecular formula, and the structural formula. Chemical calculation can be used to express both the empirical formula and the molecular formula.

The next link in EKB explains how can you calculate the emprical formula:

Notice

The empirical formula, in this case, does not express the true composition of the molecule as it only shows the simplest ratio between its components.

The empirical formula, sometimes expresses the molecular formula like the carbon dioxide molecule CO_2 or the nitric oxide NO.

A number of compounds may participate in one empirical formula like acetylene C_2H_2 and aromatic benzene C_6H_6 as the empirical formula for them is (CH).

The empirical formula of the compound can be calculated in terms of the weight percentage of the elements forming it as the weight percentage represents the mass of these elements found in every 100 g of the compound.

Example:

Calculate the empirical formula of a compound containing nitrogen with a weight percentage of 25.9% and oxygen with a weight percentage of 74.1% knowing that (N = 14, O = 16).

Solution:

Number of nitrogen moles $= \frac{25.9}{14} = 1.85$ mol

Number of oxygen moles $= \frac{74.1}{16} = 4.63$ mol

The ratio between the number of O moles : number of N moles is 1.85 : 4.63 , by dividing by the less number to find a simple ratio between the number of moles.

N	:	O
$\frac{1.85}{1.85}$	:	$\frac{4.63}{1.85}$
1	:	2.5

This ratio does not express the empirical formula, but when multiplying on the coefficient (2), the empirical formula becomes N_2O_5.

Molecular formula: is a symbolic formula of the molecule of the element, or molecule or the formula unit. It expresses the actual type and number of atoms or ions that form this molecule or unit.

The molecular formula of a compound can be calculated by knowing the molar mass of it and its empirical formula then multiplying it in the number of its units.

Notice

$$\text{Number of units of the empirical formula} = \frac{\text{Molar mass of the compound}}{\text{Molar mass of the empirical formula}}$$

Example:

Chemical analysis have proven that acetic acid (vinegar acid) is formed from 40% carbon, 6.67% hydrogen, and 53.33% oxygen. If the molecular molar mass of it is 60 g, infer the molecular formula of the acid knowing that (C = 12 , H = 1 , O = 16).

Solution:

	O	H	C
Calculation of number of moles =	$\frac{53.33}{16}$	$\frac{6.67}{1}$	$\frac{40}{12}$
	3.33	6.67	3.33
Ratio between the numbers of moles =	1 :	2 :	1 divid on the smallest number of moles
Empirical formula =	O	H_2	C

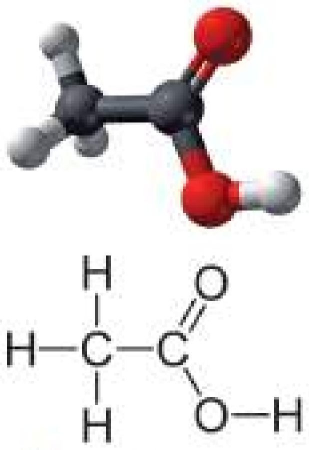
Calculation of the molecular mass of the empirical formula =

$16 + 1 \times 2 + 12 = 30$

Calculation of the number of units of the empirical formula $= \frac{60}{30} = 2$

Molecular formula of the compound = empirical formula × units of emirical formula

$$= CH_2O \times 2 = C_2H_4O_2$$



▲ Figure (14) Acetic acid

Practical Product and Theoretical Product

Search for yourself

Dissolve 20 g of sodium chloride salts in a sufficient amount of water and then, add silver nitrates solution to it. 45 g of silver chloride has precipitated from it.

- Is it possible, by calculation, to confirm the validity of these results ?
- If there is a difference between the calculated results and the practical results, what is your explanation for this ?

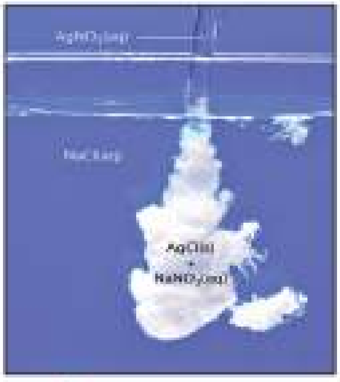


Figure (15) White precipitation from AgCl

When conducting a chemical reaction to obtain a certain chemical substance, then the reaction equation theoretically specifies certain amounts that can be gained from the produced substance and what is needed of reactant substances by units of moles or grams or others.

Practically however – and after the completion of the reaction process – the amount that we receive, called practical yield, is usually less than the calculated amount and theatrically expected. There are many reasons for this such as the product substance evaporates, and as such, much of what is produced of it does not remain. And also some of the amount may clink on to the walls of the reaction cylinder. There are also other reasons like the occurrence of competitive side reactions that consume the product substance itself or that the used substances in the reaction are not pure enough. This is called the calculated or expected amount depending on the reaction equation with the theoretical yield.

The percentage of the actual yield can be calculated from the following relation:

$$\text{Percentage of actual yield} = \frac{\text{Practical yield}}{\text{Theoretical yield}} \times 100$$

Example:

Methyl alcohol is produced under high pressure through the following reaction:

$$CO_{(g)} + 2H_{2(g)} \xrightarrow{\Delta} CH_3OH_{(l)}$$

If 6.1 g of methyl alcohol is produced from a reaction of 1.2 g of hydrogen with abundance of carbon oxide, calculate the percentage of the actual yield (C = 12 , O = 16 , H = 1).

Solution:

Molecular molar mass $CH_3OH = 1 \times 4 + 16 + 12 = 32$ g

$$2 \text{ mol of } H_2 \xrightarrow{\text{Produce}} 1 \text{ mol of } CH_3OH$$

$$4 \text{ g} \xrightarrow{\text{Produce}} 32 \text{ g}$$

$$1.2 \text{ g} \xrightarrow{\text{Produce}} X \text{ g}$$

$$\therefore \ X \text{ (mass } CH_3OH \text{ theoritical)} = \frac{32 \times 1.2}{4} \times 100 = 9.6 \text{ g}$$

$$\therefore \ \text{Percentage of actual yield} = \frac{6.1}{9.6} \times 100 = 63.54\%$$

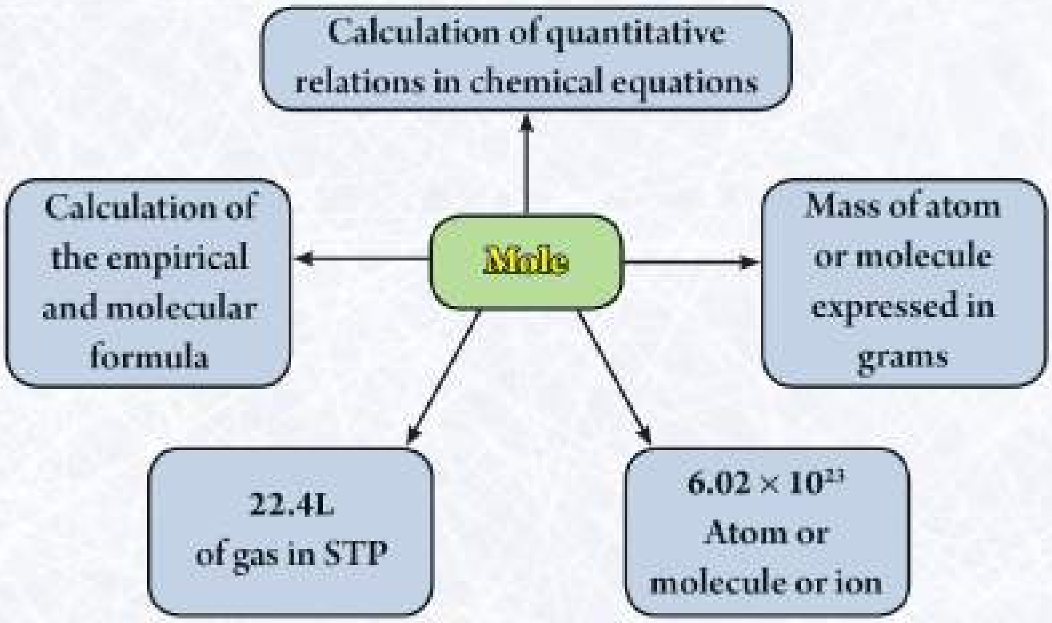
Search and Learn

Participate with some of your classmates in conducting a research on the mole and its uses in chemical calculations. Use the Internet and some references in your school library.

Basic Terminology in Unit Two

- **Chemical equation:** expresses the chemical symbols and formulas of the reactant substances and the yield from this reaction.
- **Avogadro's number:** the number of atoms, molecules, or ions found in one mole of a substance.
- **Mole:** the equal volumes of different gases contain the same number of molecules under the same standard temperature and pressure.
- **Empirical Formula:** a formula expressing the simplest ratio of true numbers between the atoms of elements in which a compound is formed.
- **Molecular formula:** is a symbolic formula of the molecule of the element, or molecule or the formula unit.
- **Theoretical yield:** the calculated or expected amount depending on the reaction equation.
- **Actual yield:** is the amount that is practically gained from the reaction.

Organizational Chart of Unit Two



Lesson One : Mole and the Chemical Equation

Laboratory Activity : Mole and the Chemical Equation

Security and Safety

Purpose of the Activity

☑ Express the chemical reaction with a balanced symbolic equation by using the chemical calculation.

Acquired Skills

☑ Using laboratory equipment – observing – recording data – concluding.

Materials

☑ Crucible – Magnesium – bunsen flame – digital balance – flask filled with pure oxygen.

Procedure :

- Bring a crucible and measure its mass.
- Measure 2.4 g of magnesium.
- Ignite the magnesium and then quickly place it inside a coned flask filled with pure oxygen and the ignition is complete and there is a transformation of magnesium oxide.
- Measure the mass of the produced magnesium oxide. What do you observe?

  Observation: ....

- Calculate the mass of the used oxygen in this reaction.

  ....

- Express the reaction with a balanced symbolic equation by using the chemical calculation, knowing that [Mg = 24, O = 16]

  ....

- Calculate the mass of the magnesium required to get 120 g of magnesium oxide.

  ....

- Use the relationship between the mole and the mass substance in calculating the number of moles of 160 g of magnesium oxide.

  ....

Conclusion :

- What are the most important conclusions that you have reached through the results of this experiment?

  ....

  ....

Unit 2
Activities and Assessment Questions

Laboratory Activity : Mole Unit and its Derivatives

Security and Safety

Purpose of the Activity

- ☑ Calculate the amount of reactant substances using a practical method.
- ☑ Calculate the number of molecules of a substance by using the relationship between the mole and the Avogadro number.
- ☑ Calculate the volume of gas in standard conditions of temperature and pressure in terms of the number of gas moles.

Acquired Skills

- ☑ Observing – explaining – recording data – analyzing – concluding.

Materials

- ☑ Baking soda (sodium bicarbonates) – bunsen flame – digital balance – watch – limewater – connecting tubes – test tubes.

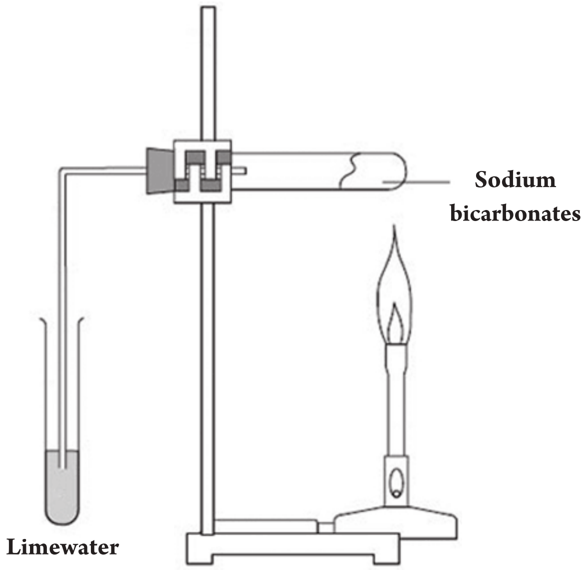
Procedure :

Cooperate with two of your classmates and perform the following activity. Compare between the results, observations, and conclusions that your reached and what the other groups reached in the classroom:

- Bring a clean and dry test tube and state its mass.
- Place a small amount of baking soda (sodium bicarbonates) and then state its mass once more. Seal it tightly with a sealer and allow a tube to permeate from it that ends from the other side inside a test tube that has a small amount of limewater.
- At the beginning, gently heat the tube on a flame and then use a strong flame for ten minutes. What do you observe?

Observation: ....

- Repeat the previous step a few times and in each time test the rising gas by using limewater until the sodium bicarbonates are completely dissolved. This is inferred because the limewater did not turbid.



- Leave the tube to cool down and then state its mass of what it contains of products after removing the sealer and the connecting tubes.
- Compare between the mass of the tube in the second step and its mass in the fifth step. What do you observe?

  Observation: ....

  ....

- If you knew that the sodium bicarbonates dissolves by heat and gives sodium carbonates and carbon dioxide gas and water vapor rise, how could you explain this observation?

  Explanation: ....

  ....

- Use the chemical calculation in writing the expressive symbolic equation from the previous reaction, knowing that [Na = 23 , C = 12 , O = 16 , H = 1]

  ....

- Calculate of the mass of baking soda (sodium bicarbonates) that participated in the previous reaction.

  ....

- Calculate of the produced water vapor molecules from this reaction.

  ....

- Calculate of the produced volume of carbon dioxide from this reaction in STP.

  ....

- Calculate the number of produced sodium carbonate moles when heating 53 g of baking soda until it is dissolved.

  ....

- Analyze your results and record your conclusions.

Analyzing and concluding:

....

....

....

Assessment Questions

Use the following atomic masses when required:

C = 12	O = 16	H = 1	N = 14	S = 32	Na = 23
Cl = 35.5	P = 31	Mg = 24	Ca = 40	Al = 27	Fe = 56

First : Choose the correct answer :

1. Number of water moles found in 36 g of it are .... moles.

A. 1 B. 2
C. 2.5 D. 0.5

2. Number of carbon dioxide molecules found in 128 g of it equals .... molecules.

A. 2 B. 6.02×10^{23}
C. 3.01×10^{23} D. 12.04×10^{23}

3. Number of produced sodium ions from dissolving 40 g of NaOH in water equals .... ions.

A. 2 B. 6.02×10^{23}
C. 3.01×10^{23} D. 12.04×10^{23}

4. The volume of 4 g of hydrogen in standard conditions (STP) equals .... liter.

A. 2 B. 22.4
C. 44.8 D. 89.6

5. The gas volume is directly proportion to the numberof its moles as its temperature and pressure are constant ....

A. Avogadro's Law B. Law of Matter Conservation
C. Avogadro's hypothesis D. Law of Mass Conservation

Second : Express the following reactions in the form of balanced ionic equations :

1. Sodium chloride solution + silver nitrate solution $\longrightarrow$ sodium nitrate solution + white precipitant from silver chloride
2. Nitric acid + potassium hydroxide solution $\longrightarrow$ potassium nitrate solution + water

Third : Rewrite the following equations after balancing them :

1. $N_{2(g)} + H_{2(g)} \xrightarrow{\Delta} NH_{3(g)}$
2. $Cu(NO_3)_{2(s)} \xrightarrow{\Delta} CuO_{(s)} + NO_{2(g)} + O_{2(g)}$
3. $Al_{(s)} + O_{2(g)} \xrightarrow{\Delta} Al_2O_{3(s)}$

Fourth : Explain :

1. The volume occupied by 26 g of acetylene C_2H_2 at (STP) is equal to the volume occupied by 2 g of hydrogen at the same conditions.
2. The difference in the molar mass of phosphorus by the difference in its physical state.
3. One liter of oxygen gas contains the same number of molecules that a liter of chlorine gas contains at STP.

Fifth : Solve the following problems :

1. Calculate the number of sodium ions that are produced from dissolving 117 g of sodium chloride in water.
2. Calculate the mass of calcium carbonate needed to produce 5.1 liters of carbon dioxide according to the reaction:

$$CaCO_{3(s)} + 2HCl_{(aq)} \longrightarrow CaCl_{2(aq)} + CO_{2(g)} + H_2O_{(\ell)}$$

Lesson Two : Calculating the Chemical Formula

Laboratory Activity : Percentage and Molecular formula

Security and Safety

Purpose of the Activity

- ☑ Calculate the percentage of hydrate water in a practically hydrate sample.
- ☑ Practically calculate the primary and molecular formula.
- ☑ Calculate the percentage of the actual product in in proportion to the the oretical product.

Acquired Skills

- ☑ Using tools – observing – measuring – using mathematical relations – analyzing.

Materials

- ☑ Stand – metal ring – flask – bunsen flame – digital balance – test tubes – sodium hydroxide solution – filtration paper.

Procedure :

- Measure the mass of the empty crucible after cleaning and drying it. Let it be m.
- Place a sample of hydrated copper sulfates in the crucible and measure the mass of the crucible once more (m_1).
- Heat the crucible on a flame for 15 to 20 minutes and then remove it from the flame. Leave it to cool down until it reaches room temperature and measure its mass. Let is be (m_a).
- Repeat the previous step once again and measure the mass of the flask. Let it be (m_b).
- If m_a does not equal m_b , repeat step three a number of times until the mass is completely fixed. Let it be (m_2).
- Compare between m_1 and m_2 . What do you notice? What is your explanation for this?

Observation: ....

....

Explanation: ....

....

- Determine the percentage for hydrate water.

- Calculate the number of moles of dry copper sulfate (after heating) knowing that [Cu = 63.5, S = 32 , O = 16]

  ....

- Calculate the number of moles of volatile water knowing that [H = 1 , O = 16]

  ....

- Follow the steps of calculating the molecular formula that you studied until you get the molecular formula of hydrated copper sulfate salt. Keep in consideration that water and dry copper sulfate are the primary elements for this formula

  Molecular formula: ....

- Dissolve dry copper sulfate salt in an amount of water to form a solution from it.
- Add few drops of sodium hydroxide solution to the solution.

  Observation: ....

- Express the previous reaction with a balanced symbolic equation and then specify the formed precipitant.

  ....

- Continue to add NaOH solution until you observe that there is no increase in the formed precipitant and then filter the precipitant on filtration paper to separate it from the solution.
- Dry the precipitant by heating it inside a clean flask of a known mass and then identify its mass. Let it be (m_3).
- Calculate the mass of the precipitant expected to theoretically form. Let it be (m_4). Compare between m_3 and m_4 . What do you observe?

  Observation: ....

- Calculate the actual product to the theoretical product.

  Ratio = ...

Analyze :

- Analyze the previous results

  ....

  ....

  ....

Laboratory Activity : Theoretical and Practical yield

Security and Safety

Purpose of the Activity

- ☑ Calculate the percentage of the actual product.
- ☑ Explain the change occurring in the actual product rather than the theoretical product.

Acquired Skills

- ☑ Using materials – chemical calculation – observation – explanation – conclusion.

Materials

- ☑ Crucible – iron filling – sulfur powder – flame – digital balance – holder.

Procedures :

- Clean the crucible well, then measure its mass.
- Use the digital balance to measure a mass of 7 g of iron filling, then place it in the crucible.
- Measure a mass of 4 g of sulfur and place it in the crucible, then identify the mass of the mixture.
- Heat the mixture on a flame until the mixture turns into black color.
- Let the product to cool then identify its mass. What do you observe?

Observation: ....

- Express the previous reaction using a balanced chemical equation.
- Calculate the mass of iron sulfide (FeS) expected to be obtained from such a reaction using the equation taking into consideration that [Fe = 56 , S = 32].
- Identify the percentage of the practical yield.
- What is your explanation of why some changes occur in the practical yield rather than the calculated theoretical yield?

Explanation: ....

Assessment Questions

Use the following atomic masses when required:

Cl = 35.5	O = 16	C = 12	H = 1	Ca = 40
S = 32	Ba = 137	Na = 23	Fe = 56	

First : Choose the correct answer :

1. The empirical formula of the compound $C_4H_8O_2$ is ....

A. $C_4H_4O_2$ B. C_2H_4O

C. $C_2H_8O_2$ D. C_4H_8O

2. The number of the empirical formula units of the compound $C_2H_2O_4$ is ....

A. 1 B. 2

C. 3 D. 4

3. The mass of CaO resulted from dissociating 50 g of calcium carbonate $CaCO_3$ thermally is .... g

A. 28 B. 82

C. 96 D. 14

4. The volume of the hydrogen needed to produce 11.2 L of water vapor at (STP) is L

A. 22.4 B. 44.8

C. 11.2 D. 68.2

5. If the empirical formula of a compound is CH_2 and its molecular mass is 56 , then the molecular formula of such a compound is ....

A. C_2H_4 B. C_3H_6

C. C_4H_8 D. C_5H_{10}

Second : solve the following problems :

1. Calculate the ratio of iron present in the raw siderite $FeCO_3$.

....

2. Calculate the mass percentage of the element forming sugar glucose $C_6H_{12}O_6$.

....

3. Infer the molecular formula of an organic compound of a molecular mass 70 g , if you know that it contains carbon with a ratio 85.7 % and hydrogen with a ratio 14.3 % .

....

4. 39.4 g of barium sulfate $BaSO_4$ precipitated when 40 g of barium chloride solution $BaCl_2$ reacted with an abundance of potassium sulfate. Calculate the percentage of the practical yield.

....

Third : write the scientific term :

1. A formula expressing the actual number of atoms or ions forming the molecule or the formula unit.

....

2. The amount of a substance which we practically obtain from a reaction.

....

3. A formula expressing the simplest ratios of integers among the element atoms forming the compounds.

....

4. The amount of the calculated substance based on the reaction's equation.

....

Unit Two Revision Questions

C = 12	O = 16	H = 1	N = 14	Na = 23	Ag = 108	Cl = 35.5

First : Choose the correct answer :

1. The masses of atomic particles are estimated by the unit of atomic masses (amu) which equals .... g

A. 6.02×10^{23} B. 1.66×10^{-24}

C. 6.02×10^{-24} D. 1.66×10^{23}

2. The unit used in the international system SI to express the amount of a substance is ....

A. Mole B. Gram

C. Kilogram D. Unit of atomic masses

3. The number of grams of 44.8 L of ammonia gas NH_3 at (STP) equals ....

A. 2 B. 17

C. 0.5 D. 34

4. If an amount of sodium contains 3.01×10^{23} atoms , then the mass of this amount equals .... g

A. 11.5 B. 23

C. 46 D. 0.5

5. If the molecular formula of vitamin C is $C_6H_8O_6$, then its empirical formula is ....

A. $C_3H_4O_6$ B. $C_3H_4O_3$

C. $C_6H_4O_3$ D. $C_3H_8O_3$

6. A chemical equation is to be balanced to satisfy .... law.

A. Avogadro B. Reservation of energy

C. Reservation of mass D. Gay – Lussac

7. Half a mole of carbon dioxide CO_2 is .... g

A. 44 B. 22

C. 88 D. 66

8. The empirical formula of CH_2O expresses the molecular formula of ....

A. HCHO B. CH_3COOH

C. $C_6H_{12}O_6$ D. All of the previous

9. When 64 g of oxygen reacts with abundance of hydrogen, then the volume of the water vapor resulted in STP is L

A. 22.4 B. 44.8

C. 11.2 D. 89.6

10. The molecular formula of the hydrocarbon compound resulted from the linkage of 0.1 mol of carbon atoms with 0.4 mol of hydrogen atoms is ....

A. C_2H_4 B. C_4H_8

C. CH_4 D. C_3H_4

Second : write the scientific term expressing each of the following :

1. The method of expressing the symbols , formulas and amounts of reactants , products and the reaction conditions.

....

2. The atomic, moleculer, ionic or formula units expressed in grams.

....

3. A constant number expressing the number of the atoms , molecules or ions in one mole of a matter.

....

4. A formula expressing the actual number of the atoms or ions forming a molecule.

....

5. The amount of a substance which we practically obtain from the chemical reaction.

....

6. The sum of the masses of the atoms forming a molecule.

....

7. The volume of the gas is directly proportional to the numberof its moles as its temperature and pressure are constant.

....

8. The equal volumes of gases at the same conditions of pressure and temperature contain the same molecules.

....

9. A formula expressing the simplest ratios of integers among the element atoms forming a compound.

....

10. The quantity of the calculated substance based on the reaction equation.

....

Third : solve the following problems :

1. Calculate the molecular formula for a compound contains carbon with a ratio 85.7 % and hydrogen with a ratio 14.3 % and its molecular mass is 42.

....

2. 130 g of silver chloride precipitated when a mole of soduim chloride dissolved in water reactd with silver nitrate solution. Calculate the following:

   A. The percentage of the actual product.

....

   B. The number of soduim ions resulted from this reaction.

....

3. Calculate the number of moles of 144 g of carbon.

....

4. Calculate the mass of 2.4 mol of a limestone $CaCO_3$

....

5. Calculate the volume of 56 g of nitrogen at (STP)

....

6. Calculate the volume of hydrogen and the number of sodium ions resulted from the reaction of 23 g of sodium and an excess amount of water in the standard conditions according to the following equation:

$$2Na_{(s)} + 2H_2O_{(\ell)} \longrightarrow 2NaOH_{(aq)} + H_{2(g)}$$

....

7. Calculate the volume of one mole of phosphorus in the gasious state at (STP), then calculate the number of the atoms in this volume.

....

Fourth : give the reason :

1. The number of molecules of 9 g of water (H_2O) is equal to the number of molecules of 39 g aromatic benzine C_6H_6

....

2. The chemical equation should be balanced.

....

3. When you calculate the gas volume in terms of its molar mass, it should be placed in the standard conditions of pressure and temperature.

....

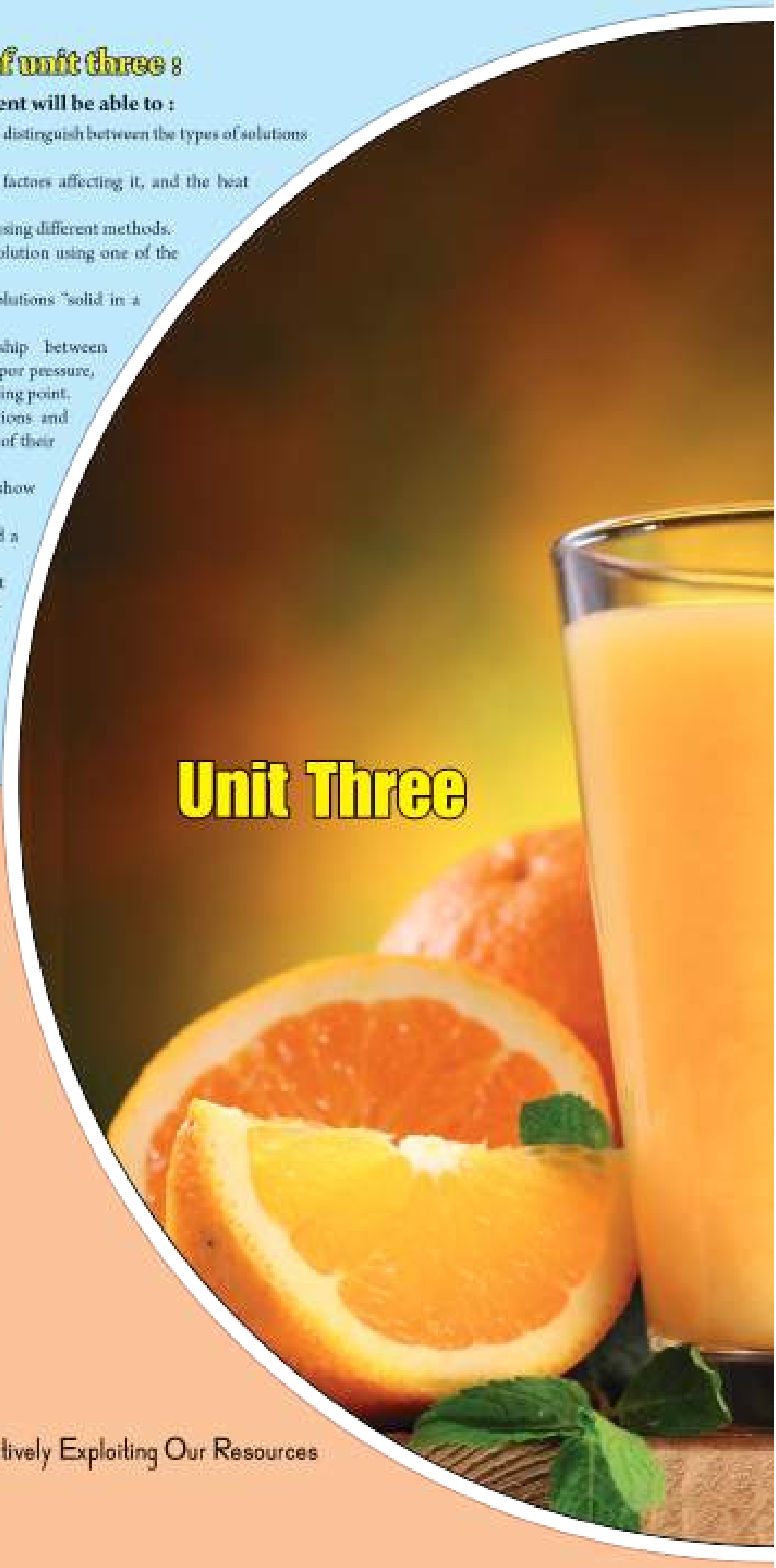
4. The practical yield is always less than the theorietical yield of the equation.

....

5. The molar mass of the sulfur in the solid state differs from its molar mass in the gaseous state.

....

Unit Three



General objectives of unit three :

By the end of this unit, the student will be able to :

- Explain what is meant by solution and distinguish between the types of solutions by practical experiments.
- Describe the solubility process, the factors affecting it, and the heat changes accomplished with it.
- Show the concentration of solutions using different methods.
- Calculate the concentration of the solution using one of the concentration units.
- Identify the general properties of solutions "solid in a liquid".
- Represent the graphical relationship between concentration of the solution, the vapor pressure, and the change in its boiling and freezing point.
- Compare between the colloid solutions and the real solutions in terms of the size of their compositions.
- Prepare some simple colloids and show their importance in our everyday life.
- Explain what is meant by an acid and a base, and their classifications.
- Compare between the different theories to define the acid and the base.
- Distinguish between acids and bases using indicators and the pH-meter.
- Understand how salts form, their naming, and the pH values of their solutions.

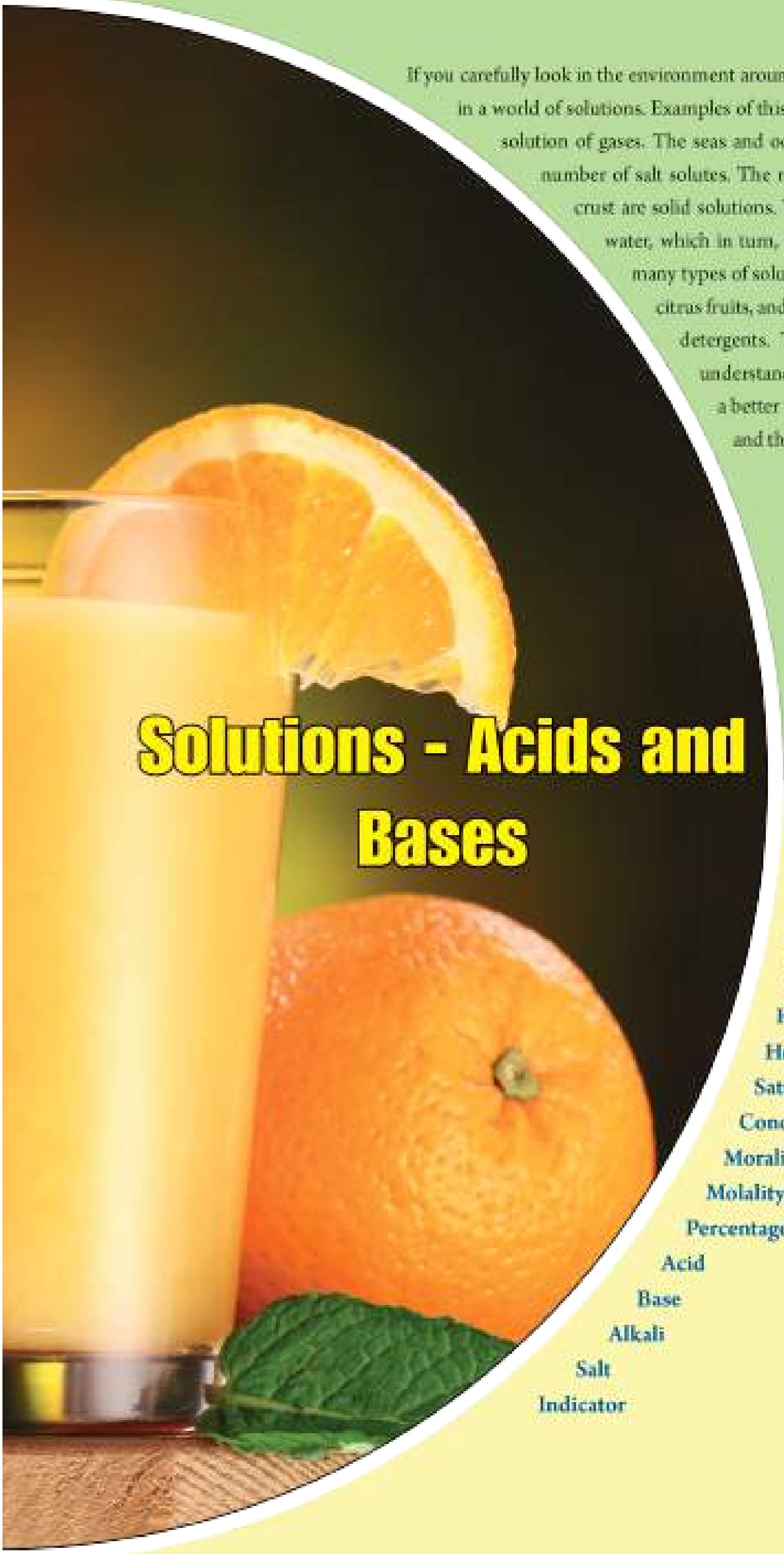
Unit Three Chapters :

1. Solutions and Colloids

2. Acids and Bases

Involved Issues : Positively Exploiting Our Resources

If you carefully look in the environment around you, you will discover that you live in a world of solutions. Examples of this include the air you breathe is a huge solution of gases. The seas and oceans are aquatic solutions of a large number of salt solutes. The rocks and metals found in the Earth's crust are solid solutions. The cells of living organisms contain water, which in turn, contain solute substances. There are many types of solutions, which maybe acidic like juices, citrus fruits, and milk or alkali like seawater and liquid detergents. Therefore, it is necessary for us to understand what solutions are in order to have a better understanding of the world we live in and the living organisms that exist in it.



Solutions - Acids and Bases

Key Terms :

- Solution
- Mixture
- Colloids
- Homogenous
- Heterogeneous
- Saturated
- Concentration
- Morality
- Molality
- Percentage
- Acid
- Base
- Alkali
- Salt
- Indicator

Lesson One : Solutions and Colloids

Learning Outcomes

By the end of this lesson, you will be able to:

- ✓ Explain what is meant by solution and distinguish between the types of solutions by practical experiments.
- ✓ Describe the solubility process "solid in a liquid", the factors affecting it, and the heat changes forthcoming with it.
- ✓ Show the concentration of solutions using different methods.
- ✓ Calculate the concentration of the solution using one of the concentration units.
- ✓ Identify the general properties of solutions "solid in a liquid" (vapor pressure – boiling point – freezing point).
- ✓ Represent the graphical relationship between concentration of the solution, the vapor pressure, and the change in its boiling and freezing point.
- ✓ Separate between the solutions and the colloid systems.
- ✓ Prepare some simple colloids.
- ✓ Clarify the importance of the colloids in our everyday life.

When adding table salt, cobalt (II) chloride, or sugar to water, they dissolve and produce a homogenous mixture called a solution. While none of them dissolve in kerosene as each component can be distinguished from the other and therefore, form a heterogeneous mixture and are called suspensions. However, if the mixture includes both the properties of the solution and the suspension, it is called a colloid. Its components can be distinguished by using a microscope, like milk, blood, aerosols, hair gel, and the mayonnaise emulsion.

▲ **Figure (1) Cobalt (II) chloride, in water is a solution**

▲ **Figure (2) Oil in water is a suspension**

▲ **Figure (3) Milk is a colloid**

Solutions

Solutions are necessary in biological processes that occur in living organisms. And sometimes they are even a main condition for certain chemical reactions. If you analyze any two samples of the same solution, you will find that they contain the same substances with the same amounts, which confirms the homogeneity inside the solution. The proof of this is the sweet taste of the sugar solution in water in any of its parts.

The solution: is a homogenous mixture of two substances or more.

The major component that has the larger ratio is usually called the solvent while the minor component with the lesser ratio is known as the solute.

Types of Solutions :

Some believe that the word solution is always connected with the liquid state of the substance. However, the solutions are classified according to the physical state for each of the solute and the solvent as clarified in the following table:

Type of Solution	Solute State	Solvent State	Examples
Gas	Gas	Gas	Air – natural gas
Liquid	Gas	Liquid	Soft drinks - oxygen dissolved in water
	Liquid		Alcohol in water – ethylene glycol (anti-freeze) in water
	Solid		Sugar or salt in water
Solid	Gas	Solid	Hydrogen in platinum or palladium
	Liquid		Silver amalgam $Ag_{(s)}$ / $Hg_{(\ell)}$
	Solid		Alloys like nickel – chrome alloy

▲ Table (1) Types of solutions

We will concentrate in our study of this section on the solutions of the type "solid in a liquid" in which water is the solvent.

Add to your Information

Electronegativity: is the ability of atom to attract the bonded electrons to itself.

Polar bonds: is a covalent bond between two different atoms in the electronegativity. The higher electronegative atom carries a partially negative charge (δ^-) while the other carries a partially positive charge (δ^+).

Polar molecules: are the molecules that have an end carrying a partially positive charge (δ^+) and another end carrying a partially negative charge (δ^-). This depends on the polarity of the bonds, the angles between these bonds and its stereostructure.

Water is a Polar Solvent :

The bonds in a water molecule are polar bonds because the electronegativity of oxygen is higher than that of hydrogen. Therefore, oxygen atom carries a partially negative charge (δ^-) while the hydrogen carries a partially positive charge (δ^+). In addition to the value of the angle between the two bonds in the water molecule is approximately 104.5° .

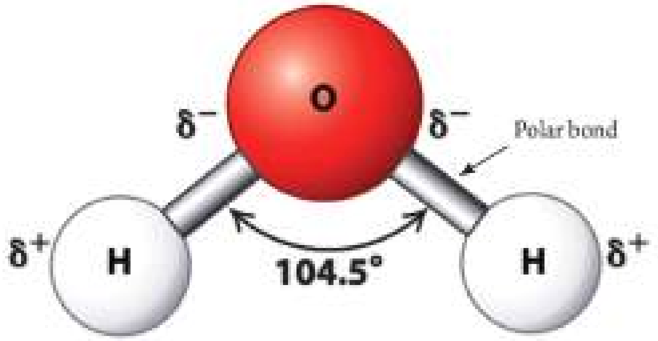


Figure (4) The angle between the two bonds in the water molecule

Electrolytes and non-electrolytes solutions :

Electrolytes: are the substances which their solutions or molten conduct the electric current through their ions .

Electrolytes are divided into:

- **Strong electrolytes:** conduct the electrical current to a large extent as it is completely ionized, i.e. all its molecules are dissociated into ions. Examples of this are:

✓ Ionic compounds are like sodium chloride NaCl – sodium hydroxide NaOH.

✓ Polar covalent compounds like hydrogen chloride gas HCl which conducts the electrical current in the case of its solution in water , and does not conduct the electrical current in its gaseous state.

Notice

When hydrogen chloride gas is dissolved in water and the hydrogen ion H^+ is separated , it does not remain in its single form , but is attached to water molecule forming the hydronium ion H_3O^+ as in the following equation:

$$HCl_{(g)} + H_2O_{(\ell)} \longrightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}$$

- **Weak electrolytes:** conduct the electrical current to a weak extent as it is partially ionized, i.e. a small part of its molecules are ionized into ions. Examples of this are: acetic acid CH_3COOH and ammonium hydroxide NH_4OH and water H_2O.

Non-electrolytes: are the substances in which its solutions or its moltens do not conduct the electric current since there are no free ions.

- **Non-electrolytes:** do not have the ability to ionize like sugar and ethyl alcohol.

Dissolving Process :

Substances that easily dissolve in water include ionic and polar compounds. While the non-polar molecules like methane, oil, grease, fat, or gasoline – all do not dissolve in water inspite their but dissolve in benzene. To understand this difference, we have to know the structure of solvent and solute and the attraction between them during dissolving process.

The water molecules are in continuing motion due to its kinetic energy. When placing a crystal of sodium chloride NaCl, as an example of an ionic compound, in water, the polar water molecules collide with the crystal and attract the solute ions. The dissolving of sodium chloride starts as soon as the sodium ions Na^+ and the chloride ions Cl^- separate away from the crystal. The solution forms from ions or molecules that have approximate diameters of 0.01 : 1 nm distributed in a systematic shape inside the solution. Therefore, the solution is homogeneous in its composition and properties and light can pass through it.

When a small amount of sugar is added to water, the polar sugar molecules are separated and bonded with water molecules by hydrogen bonds and dissolving process occures.

Dissolving process: Is the process occurs when the solute decomposes or dissociates into negative and positive ions or into separated polar molecules. Each of them binds to the molecules of the solvent.

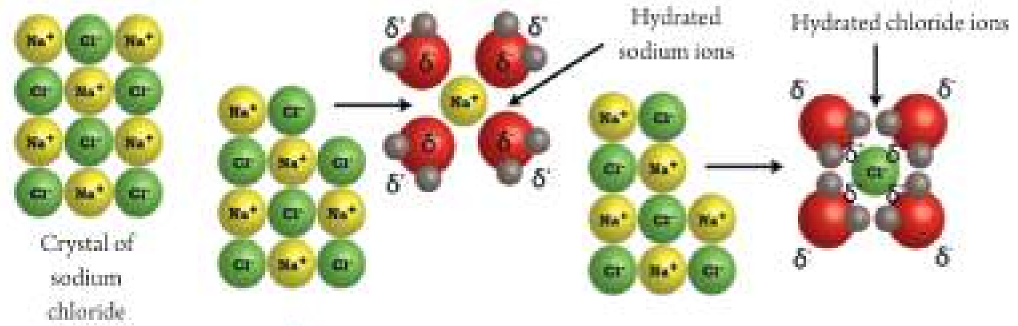


Figure (5) Solubility of NaCl in water

The speed of the dissolving process can be controlled by some factors like the surface area and the stirring process and temperature.

How does oil dissolve in benzene?

Each of them is formed from non-polar molecules. When mixed together, the oil or fat molecules spread between the benzene molecules due to the weak bonds between its molecules and settles to form a solution. As a rule, the polar solvents dissolve the ionic compounds and the polar molecules while the non-polar solvents dissolve the non-polar compounds. This relation can be summarized in the saying that 'similar substances dissolve with each other.

Solubility :

Solubility means the ability of the solute to dissolve in a certain solvent or the ability of the solvent to dissolve a certain solute.

Degree of solubility: is the mass of the solute by grams which dissolves in 100 grams of the solvent to form a saturated solution at standard conditions.

Factors affecting solubility :

1. The nature of the solute and solvent :

There is a main rule that controls the the slulibility which is (Like Dissolves Like) this means that the polar solvent dissolves the ionic and polar solutes as the solubility of nickel nitrates (ionic material) in water (polar solvent). nonpolar (organic) dissolve the solutes as the dissolving of iodine (nonpolar material) in methylene dichloride diochloride (organic solvent).

2. Temperature :

The solubility of most solid substances increases with the raising of temperature. For example, it is clear from the opposite diagram that the solubility of potassium nitrates increases by the raising of temperature. At 0°C it was 12 g and at 52°C it became 100 g. While in some salts the effect of temperature on its solubility is weak like NaCl and in other salts it decreases by the raising of temperature.

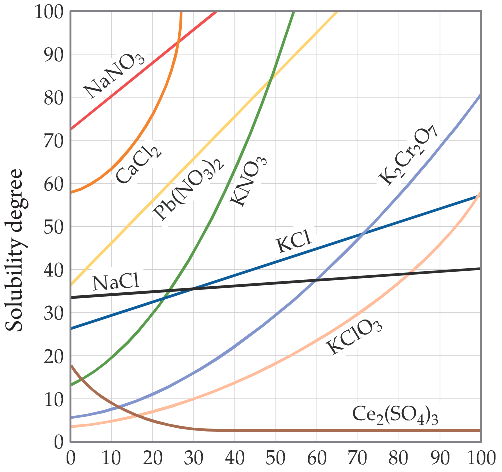


Figure (6) The relationship between solubility and temperature

The classification of the solution can be classified according to the degree of saturation into:

- **Unsaturated solution:** it is the solution in which the solvent accepts more of the solute at a certain temperature.
- **Saturated solution:** it is the solution in which the solvent contains the maximum amount of the solute at a certain temperature.
- **Super saturated solution:** it is the solution that accepts more of the solute substance after reaching a state of saturation. It can be obtained by heating the saturated solution and adding more of the solute to it. If left to cool down, the molecules of the extra solid substance separates from the saturated solution at cooling or when placing a small crystal from the dissolved solid substance in this solution as the extra substance collects on this crystal in the form of crystals.

Concentration of solutions :

As the solution is a mixture, then its components are not of certain amounts. The amount of solute can be controlled inside a certain amount of the solvent which effects the concentration of the solution. Therefore, we use the terms 'concentrated solution' when the amount of solute is large (not larger than the solvent). We also use the term 'diluted' when the amount of the solute is small in proportion to the amount of the solvent. There are different methods to express the concentration of solutions like percentage – molarity – molality.

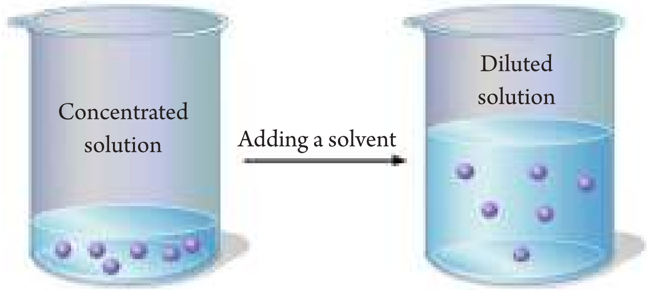


Figure (7) Concentrated solution and diluted solution

Percentage :

The concentration calculation method by using the percentage depends on the nature of the solute and solvent:

$$\text{Percentage (volume - volume)} = \frac{\text{Solute volume}}{\text{Solution volume}} \times 100$$

$$\text{Percentage (mass - mass)} = \frac{\text{Solute mass}}{\text{Solution mass}} \times 100$$

As the solution mass = solute mass + solvent mass

Due to the existence of a different types of percentages for solutions, the stickers placed on products must show the units that express the percentage like the stickers of nutritional substances, medicines, and others.

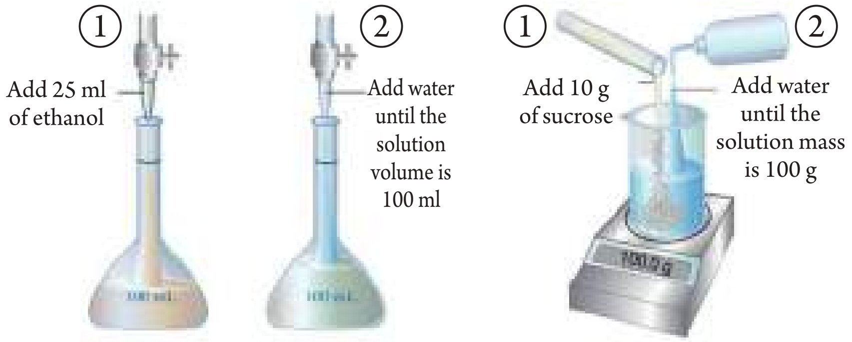


Figure (8) Percentage in terms of mass or volume

Example:

Calculate the mass percentage (m/m) of the solution resulted from the dissolving of 20 g of NaCl in 180 g of water.

Solution:

Mass = 20 + 180 = 200 g

$$\text{Solution mass percentage} = \frac{\text{Solute mass (g)}}{\text{Solution mass (g)}} \times 100\ \% = \frac{20\ \text{g}}{200\ \text{g}} \times 100\ \% = 10\ \%$$

Molarity (M) :

The solution concentration can be expressed by the term “molarity”.

Molarity: the number of solute moles dissolved in one liter of solution

It is estimated by the unit (mol/L) or molar (M)

$$\text{Molarity (M)} = \frac{\text{Number of moles (mol)}}{\text{Solution volume (L)}}$$

Example:

Calculate the molarity for a sugarcane solution $C_{12}H_{22}O_{11}$ in water, if you knew that the mass of the dissolved sugar is 85.5 g in a solution volume of 0.5 L (C =12 , H = 1 , O = 16).

Solution:

Molar mass of the sugarcane = 16 × 11 + 1 × 22 + 12 × 12 = 342 g / mol

$$\text{Number of sugar moles} = \frac{85.5 \text{ g}}{342 \text{ g / mol}} = 0.25 \text{ mol}$$

$$\text{Molarity (M)} = \frac{0.25 \text{ mol}}{0.5 \text{ L}} = 0.5 \text{ mol / L}$$

Molality (m) :

Molality: number of solute moles in one kilogram of solvent

It is estimated by the unit (mol/kg) and is calculated from the relation

$$\text{Molality (mol/kg)} = \frac{\text{Number of solute moles (mol)}}{\text{Solvent mass (kg)}}$$

Example:

Calculate the molality of a prepared solution by dissolving 20 g of sodium hydroxide in 800 g of water, knowing that (Na = 23 , H = 1 , O = 16)

Solution:

Molar mass NaOH = 1 + 16 + 23 = 40 g / mol

$$\text{Number of moles NaOH} = \frac{20}{40} = 0.5 \text{ mol}$$

$$\text{Molality (m)} = \frac{0.5}{0.8} = 0.625 \text{ mol / kg}$$

Collective Properties :

The properties of a pure solvent differs from its properties when dissolving a non-vollatile, solid substance in a group of collegative properties, such as vapor pressure, boiling point, and freezing point.

Vapor Pressure :

Vapor Pressure: the pressure that vapor affects on the liquid surface when it is at a dynamic equilibrium with the liquid inside a closed container at a constant temperature and pressure.

The vapor pressure depends on the temperature of the liquid. As the temperature increases, the rate of vaporization increases and the vapor pressure of the liquid increase as well. If the temperature continues to rise until the vapor pressure becomes equal to the atmospheric pressure, the liquid starts to boil. In this case, the boiling point is called the normal boiling point.

figure (9) evaporation speed = condensation speed

The purity of a liquid can be detected through its boiling point. So if its boiling point is identical to normal degree, this proves the purity of the liquid.

In a pure solvent, all surface molecules exposed to the vaporization process is limited to that liquid. And the only force that has to be overcome is the attraction force between the solvent molecules and each other. However, when adding a solute, the vapor pressure of the solvent decreases because some surface molecules become solute molecules that decrease the surface area of the solvent exposed to vaporization. The attraction force between the solvent molecules and the solute molecules also become larger than that between the solvent molecules and each other. The vapor pressure depends on the number of solute particles and not on its composition or property.

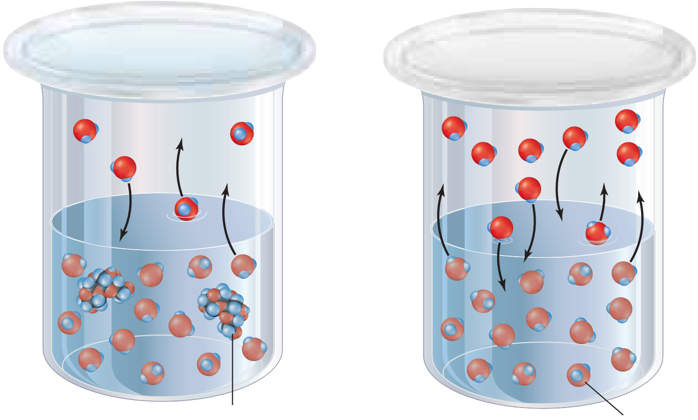
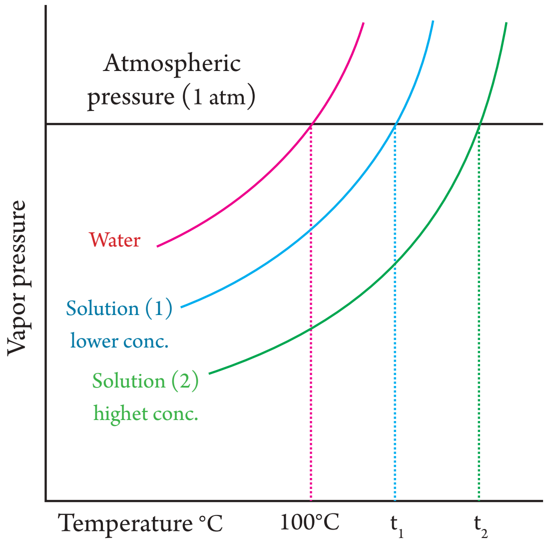


Figure (10) Vapor pressure of pure solvent is greater than that of solution contains non volatile solute

Boiling Point :

The natural boiling point: the temperature in which the vapor pressure of the liquid equals the atmospheric pressure.

Pure water is boiled at 100°C. However, salt water is not so since the addition of salt to water raises the boiling point of the solution than pure water as the salt particles decrease the water molecules that escape from the liquid surface and thus, the vapor pressure decreases and water needs more energy to evaporate. Therefore, the boiling point increases. This is repeated with any nonvolatile solute that is added to the solvent. As shown in this graph t_1 is the boiling point of solution 1 while t_2 is the boiling point of solution 2. For example, the solution 0.2 M of table salt NaCl causes the same change that occurs to the solution 0.2 M of potassium nitrates KNO_3 because each of them produce the same number of ion in the solution. However, if we use the solution 0.2 M of sodium carbonates Na_2CO_3 , the boiling point increases to a greater level due to the increase of the number of ion produced.



Measured poiling point: the temperature at which the vapour pressure of the liquid equals the pressure exerted or acted on it.

Freezing Point :

The addition of a nonvolatile solute to a solvent has an inverse affect on the freezing point of the solution than what occurs in the boiling point.

When adding a solute to the solvent, the freezing point of the solvent decreases than its pure state due to the attraction between the solute and the solvent that prevent the solvent from transforming into a solid substance. Thus, when adding salt to snow-covered streets, the water found on these streets will not easily freeze which will prevent cars from skidding and decrease the rate of accidents.

The decreasing in the freezing point is directly proportional with the number of the dissolved solute particles in the solvent and does not depend on the nature of each of them. So when adding one mole (180 g) of glucose to 1000 g of water, the product solution freezes at -1.86°C. However, when adding one mole (58.5 g) of sodium chloride to 1000 g of water,the solution freezes at -3.72°C. This is due to that one mole of NaCl produces two moles of ions, which leads to the doubling of the decrease in the freezing point.

Test your Skills

What is the freezing point of the solution that contains one mole of calcium chloride $CaCl_2$ in 1000 g of water?

Suspensions

They are heterogeneous mixtures, if lift for a short time period, the particles of the forming substance precipitates from it to the bottom of the container without shaking. Its particles can be seen by the eye or by the microscope. If a solid substance, like sand or chalk dust is placed in water, shaken, and lift for a while; the solid substance permeates. The suspension differs from the solution and the diameter of every particle suspension is larger than 1000 nanometer. At least two substances of the suspension can be clearly identified as in the examples of the chalk, sand, and water. They can be separated by filtrating the mixture as the ultrafiltration membrane holds the suspended chalk particles, while the pure water passes through the ultrafiltration membrane.

Colloids

They are mixtures that contain particles, the diameter of each particle ranges between the diameter of the real solution particles and the diameter of the suspenion particle , i.e. ranges between (1:1000 n.m.). The substance that forms the colloidal particles is called the dispersed phase the medium in which colloidal particles are dispersed is called dispersing medium. a collid and solution can be distinguished by using the light where it scatters the colloid. The following figure shows examples of colloids

Test your Skills

Why is not there a gas colloid system in a gas ?

Figure (10) Examples of some colloids

The following table reveals some colloids that are specified according to the nature of the dispersed phase, the dispersing medium, and some life applications for it:

Dispersed phase	Dispersing medium	Life Applications for Colloids
Gas	Liquid	Some types of creams
Gas	Solid	Some types of sweets made of sugar and egg whites
Liquid	Liquid	Emulsion of oil, vinegar, milk and mayonnaise
Liquid	Gas	Fog , aerosols
Liquid	Solid	Hair gel
Solid	Gas	Dust and air particles
Solid	Liquid	Pigmented ink and blood , starch in hot water

Table (2) Colloidal mediums / phases

The properties of colloids differ from the real solutions and the suspensions. As many of them, at concentration, take the form of milk or clouds. However, it appears clear at severe dilution, the ultrafiltration membrane does not hold its particles, and if left for a while without shaking, it does not permeate at the bottom of the solution.

Preparation Methods for Colloids :

The most known methods for preparing colloids is the continuous method and the condensation method:

- Dispersion method: the substance is crushed into small particles until its size reaches the size of colloid particles. It is then added to the continuous medium while stirring (starch in water).
- Condensation method: the small particles are collected together into larger and more appropriate particles by chemical reactions like oxidization, reduction, or hydrolysis.

$$2H_2S_{(aq)} + SO_{2(g)} \longrightarrow 3S_{(colloid)} + 2H_2O_{(\ell)} \quad \text{(oxidation)}$$

Lesson Two : Acids and Bases

Learning Outcomes

By the end of this lesson, you will be able to:

- ✓ Explain what is meant by acid and base and their classifications.
- ✓ Compare between the different theories to explain the acid and the base.
- ✓ Distinguish between the acids and bases by using different evidences.
- ✓ Explain the meaning of Ph and its usages.
- ✓ Know the methods of forming salts and explain the Ph of their solutions.
- ✓ Naming the salts by its two parts.

What is meant by an acid or a base ?

The acids and bases represent a large part of human life. For example, the vinegar that is used in some foods and cleaning processes is an acidic solution that was early discovered. Nowadays, acids have come to use in many chemical industries like fertilizers, explosives, medicines, plastic and car batteries. Similarly, bases also have many usages at home and in chemical industries like soap, industrial detergents, medicines and dyes.

Tomatoes - acid

Medicine pills - some are acid and others are base

Industrial detergent - base

Lemon - acid

The following table shows some of the natural and industrial products, and the acids and bases entering in its composition or preparation.

Product	Acid or base entering in its composition or preparation
Acidic plants (lemon, orange, tomatoes)	Citric acid – ascorbic acid
Dairy products (cheese, milk, yogurt)	Lactic acid
Soft drinks	Carbonic acid – phosphoric acid
Soap	Sodium hydroxide
Baked soda	Sodium bicarbonate
Washing soda	Hydrated sodium carbonate

▲ Table (3) Usages of acids and bases

- **Acid :** a compound with a sour taste. It changes the dye color of the litmus to red, reacts with the active metal producing hydrogen gas

  $Zn_{(s)} + 2HCl_{(aq)} \longrightarrow ZnCl_{2(aq)} + H_{2(g)}$

  and reacts with carbonate or bicarbonate salts causes effervesence and producing carbon dioxide gas, reacts with the bases giveing salt and water.

  $Na_2CO_{3(s)} + H_2SO_{4(aq)} \longrightarrow Na_2SO_{4(aq)} + H_2O_{(l)} + CO_{2(g)}$

- **Base :** a compound with a bitter taste and slippery feel. It changes the dye color of the litmus to the blue color, reacts with the acids, and gives salt and water.

The external appearance of the acid and base leads us to an experimental definition for each. However, we must take into consideration that the experimental definition is based on observation and does not describe or explain the unseen properties that lead to that behavior. The more overall definition, that gives scientists the chance to predict the behavior of these substances comes from the studies and experiments that were placed in the form of theories.

The theories placed to describe acid and base

The Arrhenius Theory :

The electrical conductivity of aqueous solutions of acid and base proves the existence of free ions in it. When hydrogen chloride gas dissolves in water, it ionizes into hydrogen ions and chloride ions.

$$HCl_{(g)} \xrightarrow{water} H^+_{(aq)} + Cl^-_{(aq)}$$

Also when sodium hydroxide dissolves in water, it dissociate to sodium ions and hydroxide ions.

$$NaOH_{(s)} \xrightarrow{water} Na^{+}_{(aq)} + OH^{-}_{(aq)}$$

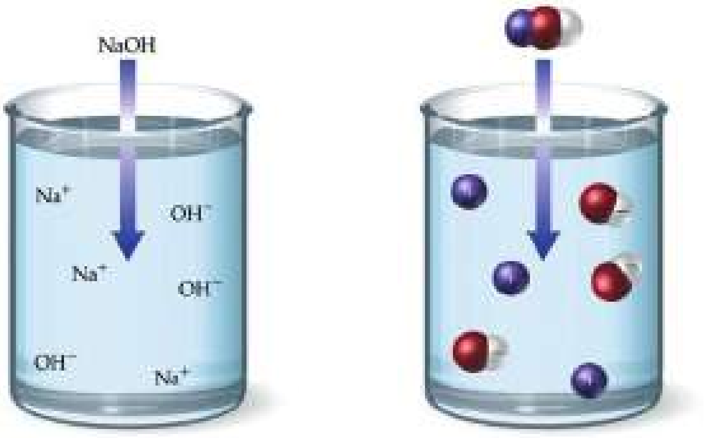


Figure (13) Sodium hydroxide solution in water

The ionization of acids and bases in water have different patterns. The first scientist who observed this, at the end of the nineteenth century, was the Swedish scientist, Arrhenius.

$$H_2SO_{4(aq)} \longrightarrow H^{+}_{(aq)} + HSO^{-}_{4(aq)} \quad \text{Sulfuric acid}$$

$$KOH_{(aq)} \longrightarrow K^{+}_{(aq)} + OH^{-}_{(aq)} \quad \text{Potassium hydroxide}$$

In 1887, Arrhenius revealed his theory that explained the nature of acids and bases, which stated that:

Acid: the substance that ionizes or dissociates in water and gives one or more hydrogen ions H^+

Base: the substance that ionizes or dissociates in water and gives one or more hydroxide ions OH^-

According to this theory, we observe that the acids work on increasing the concentration of positive hydrogen ions H^+ in aquatic solutions. This requires that Arrhenius's acid to contain hydrogen as a source of hydrogen ions as clarified from the equations of ionization or dissociation of acids. From another point, the base works on increasing the concentration of hydroxide ions in aquatic solutions. And therefore, Arrhenius's base must contain the hydroxide group OH^- as shown from the equations of ionization or dissociation of bases. Arrhenius's theory helps in explaining what occurs when there is neutralization between the acid and the base to form an ionic compound (salt) and water, as shown in the following equation:

$$HCl_{(aq)} + NaOH_{(aq)} \longrightarrow NaCl_{(aq)} + H_2O_{(\ell)}$$

The expressive ionic equation of this reaction according to Arrhenius's theory is:

$$H^{+}_{(aq)} + OH^{-}_{(aq)} \longrightarrow H_2O_{(\ell)}$$

And therefore, water becomes an essential product when neutralization occurs between the acid and the base.

Observations on Arrhenius's theory:

- Carbon dioxide and other compounds give acidic solutions in water, however they do not contain ion H^+ in their structure. this does not match with **Arrhenius's theory**.
- Ammonia and some other compounds give aqueous solutions inspite that it does not contain the hydroxide ion in its structure. It is also neutralized with acids and this does not agree with Arrhenius's theory.

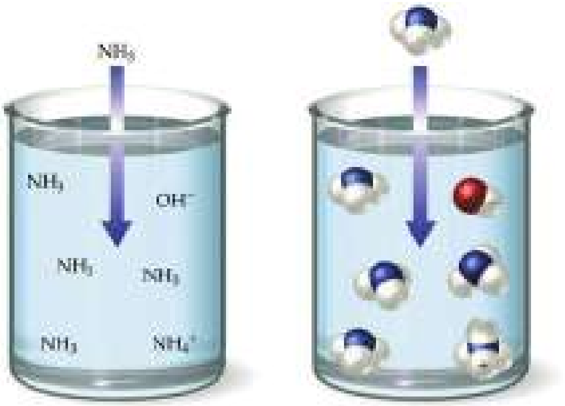


Figure (15) Ammonia solution in water

The Brönsted – Lowry Theory :

In 1923 , Johannes Brönsted , from Denmark , and Thomas Lowry , from England , proposed their theories on the acid and the base.

The next link in EKB explains the Brönsted-Lowry theory:

Give a scientific term:

A base gains a proton. (..............................)

$$HA + B \rightleftharpoons A^- + BH^+$$

HA: Acid (proton donor) + B: Base (proton acceptor) ⇌ A^-: Conjugate base + BH^+: Conjugate acid

When dissolving hydrogen chloride gas in water, HCl is considered an acid because it donates a proton to the water. And therefore, water is considered a base because it accepts that proton and the chloride ion Cl^- becomes a conjugate base while the hydronium ion H_3O^+ becomes a conjugated acid.

HCl	H_2O	Cl^-	H_3O^+
Acid	Base	Conjugate base	Conjugate acid

This definition allows us to consider ammonia as a base. This is shown in the following equation:

$$NH_{3(g)} + H_2O_{(l)} \rightleftharpoons OH^-_{(aq)} + NH_4^+{}_{(aq)}$$

$NH_{3(g)}$	$H_2O_{(l)}$	$OH^-_{(aq)}$	$NH_4^+{}_{(aq)}$
Base	Acid	Conjugate base	Conjugate acid

When the acid donates a proton, it transforms into a base and when the base accepts this proton, it transforms into an acid.

> Conjugate acid: the product when the base accepts a proton.
>
> Conjugate base: the product when an acid loses a proton

Lewis's Theory :

In 1923 G. N. Lewis proposed an acid-base theory :

- Lewis acid: is a substance that accepts an electron pair or more
- Lewis base : is a substance that donates an electron pair or more

Example: when hydrogen ion H^+ reacted with fluoride ion F^-, H^+ is considered As Lewis acid, while F^- is considered as Lewis base

$$H^+_{(aq)} + :\ddot{F}:^-_{(aq)} \longrightarrow HF_{(aq)}$$

Classification of Acids and Bases

First: Acids

Acids can be classified according to some basis as follows:

1. According to the degree of ionization in the solution, it is divided into:

- **Strong acids:** they are acids that are completely ionized, i.e. all its molecules dissociate in the solution into ions. Its solutions conduct an electrical current to a proportionately large extent due to its containing a large amount of ions. Therefore, they are considered strong electrolytes like

Hydroiodic acid HI , perchloric acid $HClO_4$, hydrochloric acid HCl , sulfuric acid H_2SO_4 , nitric acid HNO_3

- **Weak acids:** they are acids that are partially ionized, i.e. a small part of the molecules ionized into ions and conduct an electrical current to a small degree. Therefore, they are considered weak electrolytes like acetic acid (vinegar) CH_3COOH that ionizes in water into hydronium ion and acetate anion.

$$CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$$

Notice

There is no relation between the strength of the acid and the number of hydrogen atoms in its molecular structure. As the phosphoric acid H_3PO_4 contains three hydrogen atoms in each molecule. In spite of this, it is an weaker than the nitric acid HNO_3 that contains one hydrogen atom.

Figure (16) A strong acid conducts an electrical current to a greater extent than a weak acid

2. According to its source, it is divided into:

- Organic acids: they are the acids that have an organic origin (plant – animal) extracted from the organs of living organisms. They are weak acids like: formic acid – acetic acid – lactic acid – citric acid – oxalic acid.
- Mineral acids: they are the acids that usually have non-metal elements in their composition like chlorine, sulfur, nitrogen, phosphorous, and others. They have not organic origin like: hydrochloric acid HCl – phosphoric acid H_3PO_4 – perchloric acid $HClO_4$ – carbonic acid H_2CO_3 – nitric acid HNO_3 – sulfuric acid H_2SO_4

Figure (17) Citric acid in lemons

Figure (18) Lactic acid in milk and its products

Figure (19) Carbonic acid in soft drinks

3. According to the number of hydrogen atoms, the acid reacts through it, and is known as the basisty of the acid:

- Monobasic acid:

  When it dissolves in water, each molecule gives one proton

  Hydrochloric acid HCl — Acetic acid CH_3COOH

  Nitric acid HNO_3 — Formic acid HCOOH

- Dibasic acids:

  When it dissolves in water, each molecule gives one or two protons

  Sulfuric acid H_2SO_4

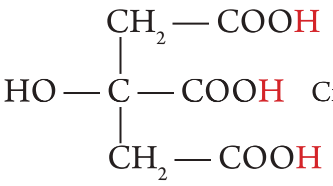
  Carbonic acid H_2CO_3

  Oxalic acid COOH | COOH

- Tri – basic acids:

  Can give up to three protons during reaction.

  Phosphorous acid H_3PO_4



Citric acid

Go Further

For more knowledge about this topic you can refer to the Egyptian Knowledge Bank (EKB) through the opposite link.

Second: Bases

Bases can be classified according to some rules as follows:

1. According to its ionization degree as follows:

- Strong bases: they are completely ionized bases. They are considered strong electrolytes as like potassium hydroxide KOH , sodium hydroxide NaOH , barium hydroxide $Ba(OH)_2$.
- Weak bases: they are partially ionized bases. They are considered weak electrolytes like ammonium hydroxide NH_4OH.

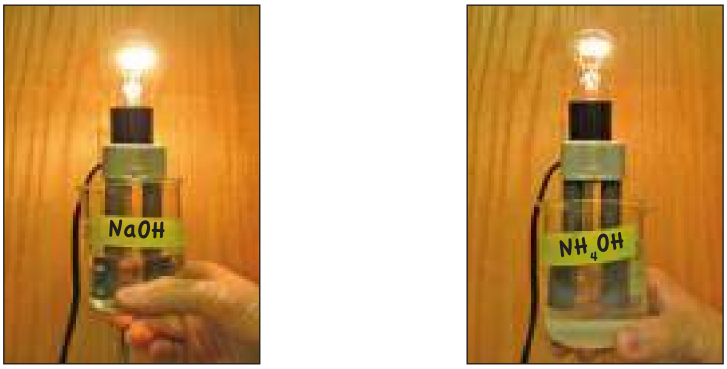


Figure (20) The strong base conducts an electrical current to a larger degree than the weak base

2. According to its molecular composition:

Some substances react with the acid to give salt and water. Therefore, they are considered bases like:

- Metal oxides – FeO:

$$FeO_{(s)} + 2\,HCl_{(aq)} \longrightarrow FeCl_{2(aq)} + H_2O_{(\ell)}$$

- Metal Hydroxides:

$$Ca(OH)_{2(aq)} + H_2SO_{4(aq)} \longrightarrow CaSO_{4(aq)} + 2\ H_2O_{(\ell)}$$

- Metal Carbonates (or bicarbonates):

$$K_2CO_{3(s)} + 2HCl_{(aq)} \longrightarrow 2KCl_{(aq)} + H_2O_{(\ell)} + CO_{2(g)}$$

$$KHCO_{3(s)} + HCl_{(aq)} \longrightarrow KCl_{(aq)} + H_2O_{(\ell)} + CO_{2(g)}$$

The bases that dissolve in water are called alkalis. They can be defined as substances that dissolve in water and give hydroxide ion OH^- , i.e. the alkalis are part of the bases. And therefore, we can say: all alkalis are bases and not all bases are alkalis.

Detecting Acids and Bases

There are a number of methods for identifying the type of solution, whether it is acidic, alkaline, or neutral as indicators or pH–meter .

First: Indicators

They are weak acids and bases. They change color with the change of the type of solution. This is due to the variation of the ionized indicator color from the non-ionized indicator color. Indicators are used to identify the type of solution and during the titration process between the acid and the base. The following schedule shows examples of some indicators and their color in the different mediums:

Indicator	Colour in acidic medium	Colour in basic medium	Colour in neutral medium
Methyl orange	Red	Yellow	Orange
Bromothymol blue	Yellow	Blue	Green
Phenolphthalein	Colorless	Pink	Colorless
Litmus	Red	Blue	Violet

▲ Table (4) Examples of some indicators and their color in the acidic, basic acid, and neutral medium

Enrichment Information

Ant and bee bites have acidic effect , they can be treated by using the sodium bicarbonate solution , whereas the wasp and jellyfish have basic effect and can be treated by using vinegar.

Second: The hydrogen exponent pH

The pH is a way of expressing the acidity and the alkalinity degree of solutions of numbers from 0 to 14. A digital device or paper tape can be used for this.

All cases of aqueous solutions contain H^+ and OH^- , the value of pH depends on the concentration of H^+ and OH^-

- If the cocentration of $H^+ > OH^-$ the solution is acidic pH value is less than 7
- If the cocentration of $OH^- > H^+$ the solution is alkaline pH value is larger than 7
- If the cocentration of $H^+ = OH^-$ the solution is neutral solution pH value equal 7

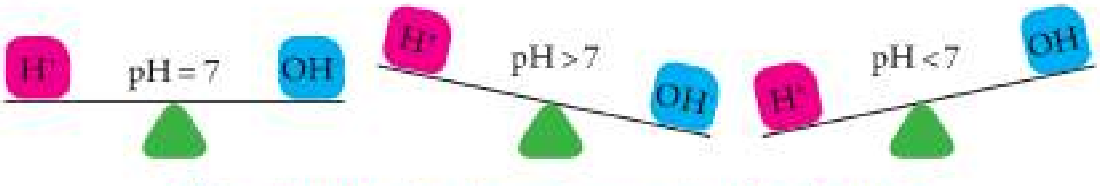


Figure (21) The relation between the cocentration of H^+ and pH value

Vinegar, lemons, tomato juice are acidic while washing soda, detergents and glair are alkaline

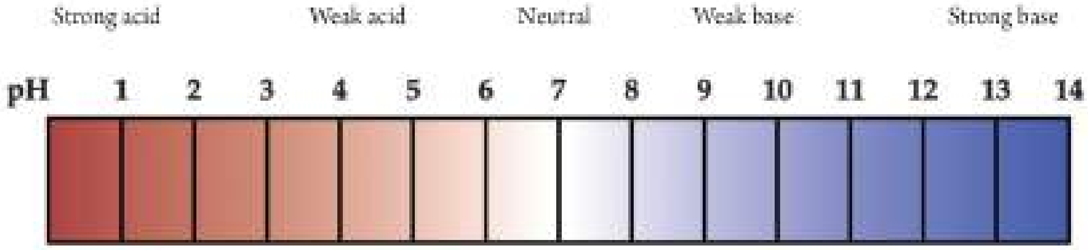


Figure (22) The pH scale

Salts

Salt Formation Methods

Salts are considered one of the types of important compounds in our life. It is abundantly found in the Earth's crust. It is also found dissolved in seawater or precipitated in the seabed. However, salts can chemically be prepared using one of the following methods:

- Reaction of metals with diluted acids: the metals that precede the hydrogen in the sequentially chemical activity replace it in the diluted acid solutions. Hydrogen rises, blows up, and salt remains dissolved in water.

$$\text{Active metal + acid} \xrightarrow{\text{dil.}} \text{salt + hydrogen gas}$$

$$Zn_{(s)} + H_2SO_{4(aq)} \xrightarrow{\text{dil.}} ZnSO_{4(aq)} + H_{2(g)}\uparrow$$

The product salt can be separated by heating the solution, so water evaporates and salt remains

- Reaction of metal oxides with acids: this method is usually used if there is difficulty in the direct reaction of metal with acid, whether it is because a dangerous reaction or due to the decrease of metal activity than the hydrogen.

$$\text{Metal oxide + acid salt + water}$$

$$CuO_{(s)} + H_2SO_{4(aq)} \xrightarrow{\Delta} CuSO_{4(aq)} + H_2O_{(\ell)}$$

- Reaction of metal hydroxide with acid: this method is suitable in the case of metal hydroxides that are dissolving in water and are considered as alkalis.

$$\text{base + acid salt + water}$$

$$HCl_{(aq)} + NaOH_{(aq)} \xrightarrow{\Delta} NaCl_{(aq)} + H_2O_{(\ell)}$$

Acids and bases reactions are known as neutralization reactions. They are used to determine an unknown concentration of an acid or alkali using an alkali or acid of a known concentration in the presence of suitable indicator. Neutralization occurs when the amount of acid is completely equivalent to the alkali amount.

- Reaction of metal carbonates or bicarbonates with most acids: it is the carbonic acid salts. It is unstable (low boiling point). It is possible for any other acid that is more stable than it to remove it from its salts and replace it. The new acid salt and water form, and carbon dioxide gas evolved. This reaction is called acidity test.

$$Na_2CO_{3(s)} + 2HCl_{(aq)} \longrightarrow 2NaCl_{(aq)} + H_2O_{(\ell)} + CO_{2(g)}\uparrow$$

Naming Salts:

Salt forms when the negative ion of the acid (anion X^-) combines with the positive ion of the base (cation M^+) to produce the salt (MY). Therefore, the chemical name of salt is formed from two parts. For example, we could say, “sodium chloride” or “potassium nitrates” The first part refers to the negative ion of the acid (anion), and is called “the acidic radical of the salt”. While the first part refers to the positive ion of the base (cation), and is called “the basic radical of the salt”. When nitric acid (HNO_3) reacts with potassium hydroxide (KOH), the resulting salt is called potassium nitrates (KNO_3)

$$KOH_{(aq)} + HNO_{3(aq)} \longrightarrow KNO_{3(aq)} + H_2O_{(\ell)}$$

The chemical formula of the resulting salt depends on the valence of the anion and cation. The following table shows examples of some salts, their formulas, and the acids in which they were prepared from.

Acid	Acidic radical	Examples for some salts
Nitric acid HNO_3	Nitrate $(NO_3)^-$	Potassium nitrates KNO_3 – lead nitrates $Pb(NO_3)_2$ iron III nitrates $Fe(NO_3)_3$
Hydrochloric acid HCl	Chloride Cl^-	Sodium chloride NaCl – magnesium chloride $MgCl_2$ aluminum chloride $AlCl_3$
Acetic acid CH_3COOH	Acetate $(CH_3COO)^-$	Potassium acetate CH_3COOK – copper II acetate $(CH_3COO)_2Cu$ iron III acetate $(CH_3COO)_3Fe$
Sulfuric acid H_2SO_4	Sulfate $(SO_4)^{2-}$ Bisulfate $(HSO_4)^-$	Sodium sulfate Na_2SO_4 – copper II sulfate $CuSO_4$ sodium bisulfate $NaHSO_4$ – aluminum bisulfate $Al(HSO_4)_3$
Carbonic acid H_2CO_3	Carbonate $(CO_3)^{2-}$ bicarbonate $(HCO_3)^-$	Sodium carbonate Na_2CO_3 – calcium carbonate $CaCO_3$ sodium bicarbonate $NaHCO_3$ – magnesium bicarbonate $Mg(HCO_3)_2$

▲ Table (5) Examples of acids and some of its salts

From the previous table, the following points are observed:

- Some acids have two types of salts like sulfuric acid and carbonic acid. This is due to the number of mobile hydrogen atoms in the acid molecule. There are acids that have three salts like phosphoric acid H_3PO_4.
- The salt that contains hydrogen in its acidic radical is either called "bi" or by adding a hydrogen word like: bisulfate HSO_4^- or hydrogen sulfate.

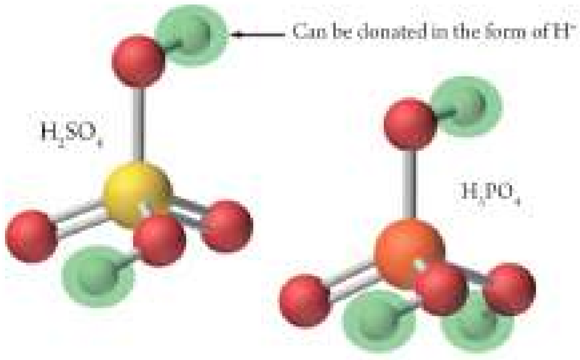


Figure (22) Acids with various salts

- The numbers II or III refers to the valence of the metal combined with the acidic radical. It is written in the case of metals that have more than one valence.
- In the case of salts of organic acids like potassium acetate $CH_3COO^-K^+$, the acidic radical is written in the symbol to the left and the basic acid to the right.

Solubility of Salts

The aquatic solutions of salts differ in their properties. Some solutions are acidic ($pH<7$) when the acid is strong and the base is weak like NH_4Cl solution. Other solutions are alkaline ($pH>7$) when the acid is weak and the base is strong like the Na_2CO_3 solution. There are also solutions that are neutral ($pH=7$) when both the acid and base are equal in strength like NaCl and CH_3COONH_4 solutions.

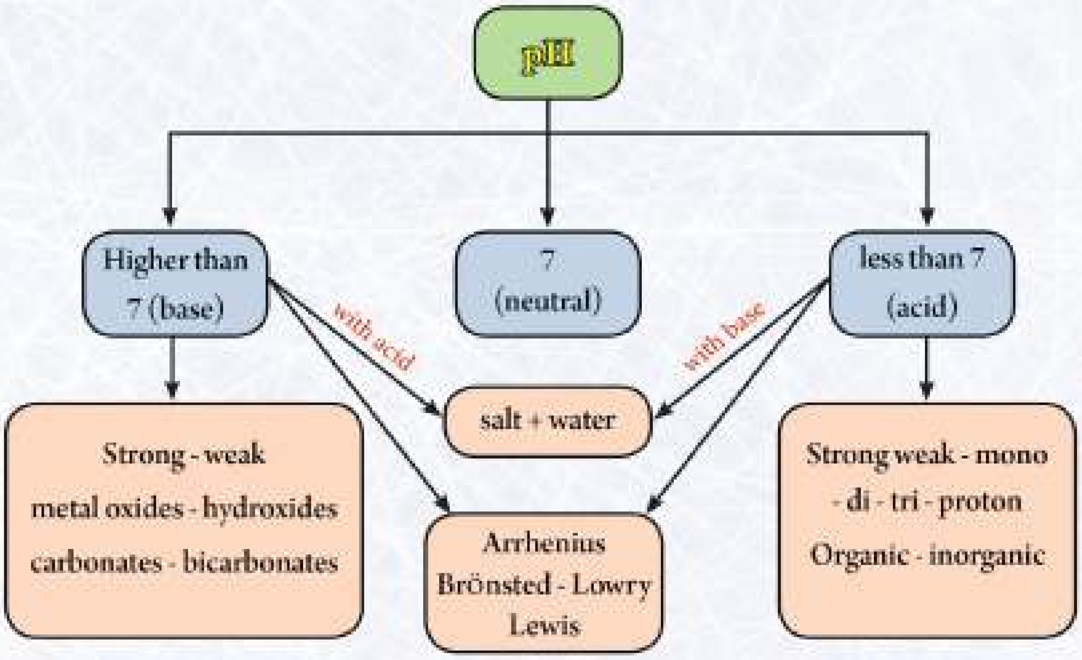
Go Further

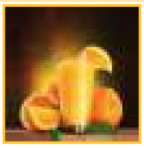
For more knowledge about this topic you can refer to the Egyptian Knowledge Bank (EKB) through the opposite link.

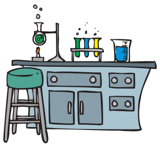
Basic Terminology in Unit Three

- **Solution:** is a homogenous mixture from two substances or more.
- **Colloids:** They are apparently homogeneous mixtures in which their particles do not permeate and it is difficult to separate their particles by filtration.
- **Arrhenius's acid:** the heterogenous solution that disassembles in water and gives one or more hydrogen ions H^+.
- **Arrhenius's Base:** the solution that disassembles in water and gives one or more hydroxide ions OH^-.
- **Brönsted–Lowry's acid:** Acid: the substance that losses the proton H^+ (proton donor).
- **Brönsted–Lowry's base:** the substance that has the ability to receive the proton (proton receiver).
- **Conjugate acid:** the product substance when the base receives a proton.
- **Conjugate base:** the product substance when an acid loses a proton.
- **Indicators (detectors):** They are weak acids and bases. They change color with the change of the type of solution.
- **pH number:** The pH number is a way of expressing the acidity and the basic acid degree of solutions of numbers from 0 to 14.

Organizational Diagram of Unit Three







Lesson One : Solutions and Colloids

Laboratory Activity : Electrolytic and non-electrolytic solutions

Security and Safety

Purpose of the Activity

☑ Classify the solutions according to their electrical current conductivity.

Acquired Skills

☑ Observation – explanation – recording data – conclusion.

Materials

☑ 6 volt battery – conducting wires – a graphite column (pencil tip) – distilled water – a 250 ml glass beaker – light bulb – glass rod – sodium chloride – copper sulphate – hydrochloric acid – vinegar (acetic acid) – sucrose – soduim hydroxide – ammonium hydroxide.

Procedures :

Co-operate with two classmates to carry out the following activity, then compare your results with other groups in the class.

- place 200 ml of water in a glass beaker.
- Form an electric circuit of a light bulb, battery and conducting wires, then connect its two ends with a graphite column (rod).
- Submerge the graphite column in water inside the glass cup without touching its wall. What do you observe on the light bulb?

  Observation : ....

- Add a little of soduim chloride(table salt) in the water, then stir it well. What do you observe on the light bulb?

  Observation : ....

- Substitute the solution in the beaker with other solutions for each of:

  $C_{12}H_{22}O_{11}$, NH_4OH , $NaOH$, CH_3COOH , HCl , $CuSO_4$

  Record your data in a table from your own designing.

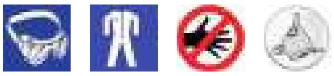
  Conclusion : ....

  Explanation : ....

Unit 3
Activities and Assessment Questions

Laboratory Activity : Preparing Solutions of Different Concentrations

Security and Safety



Purpose of the Activity

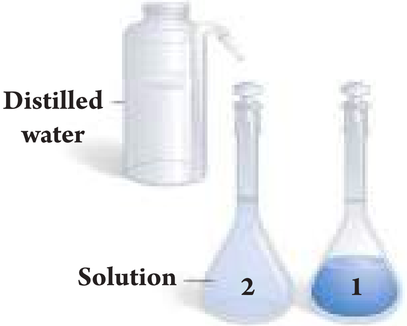
☑ Preparing solutions of different concentrations practically.

Acquired Skills

☑ Using the lab tools – observation – recording data – conclusion.

Materials

☑ Graduated cylinder – 3 standard flasks of capacity 200 ml , 250 ml and 500 ml – balance – distilled water – sodium carbonate – sodium hydroxide – hydrate copper sulfate – sodium chloride – sugar cane (sucrose) – glass rod for stirring.



Procedures :

- If you know that the atomic mass of Na , C , and O are 23, 12 and 16 respectively , calculate the molar mass of sodium carbonate.

  The molar mass = ...

  The mass of 0.2 mol of sodium carbonate = ...

- Use a balance to take a mass of 0.2 mol of sodium carbonate and place it in a flask.
- Use the graduated cylinder to place 50 ml of water on the salt inside the flask smoothly , then use the glass hand to stir.
- Complete the solution to be 200 ml and keep stirring until the sodium bicarbonate dissolves completely.
- Use the following relation to calculate the concentration of the solution :

$$\text{The molar concentration} = \frac{\text{The number of the solute moles}}{\text{The volume of the solution in liters}}$$

  The molar concentration = ...

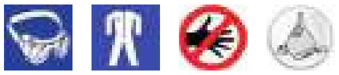
- Follow up the steps above to prepare solutions of different concentrations of sodium bicarbonates.
- Substitute sodium bicarbonates with hydrate copper sulfate. What is the change that may occur to get 1 M solution?

  ....

- Repeat the activity above using other substances such as sodium hydroxide , sodium chloride and sugar cane.
- Record the results which you conclude in a table involving the substance , its mass , number of its moles , volume of the solution and concentration.

Laboratory Activity : Comparing the types of solutions

Security and Safety



Purpose of the Activity

☑ Distinguishing the types of solutions.

Acquired Skills

☑ Using the tools – prediction – observation – inferring.

Materials

☑ 3 standard glass beakers of capacity 200 ml – distilled water – sodium chloride – milk powder – chalk powder – light torch – microscope – filtration paper – glass funnel – conical flask – glass slices – glass rod for stirring.

Milk powder

Milk is from colloids

Procedures :

- Number 3 beakers from 1 to 3.
- Put 3 g of salt in the first beaker , then add distilled water and stir until the solution volume reaches 100 ml.
- Repeat the same steps with the milk powder and chalk powder.
- Look at the mixture by your naked eye and observe if you can distinguish its components.
- Take a drop from each mixture and put it on a glass slice, then screen it under the microscope. What do you observe on the volume of the particles of each mixture?
- Put the glass funnel on the conical flask and put filtration paper inside it. Pour the salt solution inside the filtration paper. Can the salt be separated from water this way?
- Repeat the steps above with two other mixtures, then record your observation and conclusion.

Observation: ....

....

Conclusion :

- Compare between the real solution (salt solution), suspended (chalk solution) and colloidal (milk solution) in a table from your own designing and containing the following data : homogenous , volume of particles and the ability to separate the components.

....

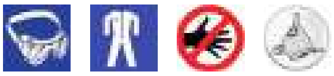
....

....

....

Laboratory Activity : Preparing some simple colloids

Security and Safety



Purpose of the Activity

- ☑ Preparing some simple colloids.
- ☑ Preparing a type of paints as an example of colloid systems.

Acquired Skills

- ☑ Using the lab tools – observation – inferring.

Materials

- ☑ 50 g of starch – 2 standard glass beakers of capacity 500 ml – distilled water – bunsen flame – glass rod.
- ☑ Glass beaker – test tube – graduated cylinder 50 ml – dropper – distilled water – bunsen flame – glass hand – lead nitrate solution 1 M sodium chromate solution 1 M – raw oil of flax seed – steaming basin – mortar – mortar hand – brush to paint – a piece of wood.

Procedures :

First : preparing starch :

- ✪ Put 50 g of starch in little cold water in the first beaker , then shake the cup well until liquid dough formed.
- ✪ Put 100 ml of distilled water in the second cup , then add the liquid dough to the water and gradually heat and stir. Observe what occurs.

Observation: ....

....

Second : preparing paints :

- ✪ Put 50 ml of lead nitrate solution 1 M in a glass beaker of capacity 500 ml , then add a similar volume of lead chromate with stirring.
- ✪ Observe the precipitant's color formed from lead chromate.

Observation: ....

....

- ✪ Wash the resulted precipitant by the distilled water by decantition method and repeat washing it several time.
- ✪ Transport the precipitant into a steaming basin to get rid of the extra humidity smoothly by slow quiet heating.
- ✪ After drying the lead chromate, put it in a mortar and use the mortar hand to grain it until it turns into a soft powder.

- Add the raw oil of flax seed to the lead chromate salt grained in the mortar, then grain the components (add what you need only of oil to get the paint which is easy to be painted by the brush). Is the product a real or colloid solution?

....

- Paint the piece of wood by a layer of the lead chromate paint you have prepared, then let it dry in air.

Assessment Questions

First : Choose the correct answer :

1. Air represents a gaseous solution of the .... type.

A. Gas in gas B. Gas in liquid
C. Liquid in gas D. Solid in gas

2. Water is polar solvent due to the difference in electronegativity between oxygen and hydrogen and the angle between the bonds whose value is about ....

A. 104.5° B. 105.4°
C. 90° D. 140.5°

3. .... is an example of strong electrolytes.

A. $H_2O_{(\ell)}$ B. Benzene
C. $HCl_{(g)}$ D. $HCl_{(aq)}$

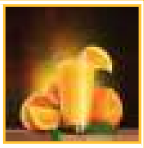
4. The unit used for expressing the molar concentration of a solution is ....

A. mol/L B. g/eq.L
C. g/L D. mol/kg

Second : what is meant of each ?

1. Solubility.

....



2. Saturated solution.

....

3. Measured oiling point.

....

Third : think and infer one reason at least for each of the following :

1. The absence of a free proton in the aqueous solutions of acids.

....

2. Water molecules have a high degree of polarity.

....

3. Raising the boiling point of sodium carbonate solution rather than sodium chloride solution, however the mass of both the solvent and solute in both solutions is constant.

....

4. Dissolving sugar in water produces a solution , while dissolving milk powder in water produces colloid.

....

Fourth : solve the following problems :

1. Add 10 g of sucrose to an amount of water of a mass 240 g , then calculate the mass percentage of sucrose in the solution.

....

2. Add 25 ml of ethanol to an amount of water , then complete the solution to 50 ml. Calculate the volume percentage (v/v) of ethanol in the solution.

....

3. Calculate the molar concentration for a solution of a volume 200 ml of sodium hydroxide. Known that the sodium hydroxide mass dissolved in it is 28 g.

....

4. Calculate the molar concentration for the solution prepared by dissolving 53 g of sodium carbonate in 400 g of water.

....

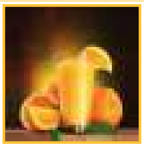
Fifth : determine the type of colloid system in each application :

1. Emulsiion of oil and vinegar.

....

2. Dust in air.

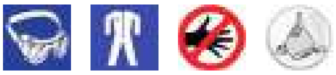
....



Lesson Two : Acids and Bases

Laboratory Activity : Distinguishing between the acidic and basic solution

Security and Safety



Purpose of the Activity

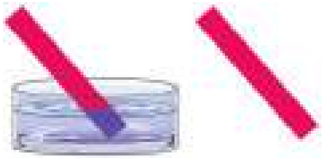
- ☑ Identify the evidences and their uses.
- ☑ Distinguishing between the acidic and basic solutions using the proper evidence.

Acquired Skills

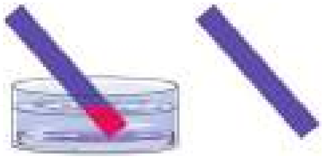
- ☑ Using the tools – observation – inferring – comparison.

Materials

- ☑ Hydrochloric acid – acetic acid – soduim hydroxide – soduim bicarbonate solution or soduim bicarbonate – red and blue litmus paper – phenolphthalein – methyl orange – test tubes and digital pH metter.



Basic solution



Acidic solution

Procedures :

- ✪ Prepare 0.1 M solution of the following substances in a way each solution is in a separate test tube and record the solution name on the tube: hydrochloric acid, acetic acid, soduim hydroxide and soduim bicarbonate.
- ✪ Put 2 litmus papers – red one and the other is blue- inside each solutions of the previous ones.
- ✪ What do you observe on the color of the 2 litmus paper.

Observation: ....

....

- ✪ Put a drop of phenolphthalein in a sample of each solution. What do you observe?

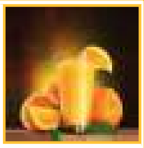
Observation: ....

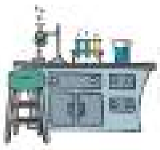
....

- ✪ Repeat the previous steps and replace phenolphthalein for methyl orange.
- ✪ Classify the previous solutions into acidic solutions and basic ones.
- ✪ Use a digital pH-metter to find the pH value for each solution, then order the solutions according to the pH value.
- ✪ Determine the strongest acidic solution and the weakest basic solution.

Conclusion: ....

....





Laboratory Activity : Chemical properties of acids

Security and Safety

Purpose of the Activity

☑ To know that when acids react with zinc, hydrogen is produced.

☑ To know that when acids react with sodium carbonate salt, carbon dioxide which turbid the clear limewater is produced.

Acquired Skills

☑ Using the tools – prediction – observation – inferring.

Materials

☑ Diluted hydrochloric acid – test tubes – zinc powder – match – sodium carbonate salt – clear limewater – diluted sulfuric acid.

Procedures :

- Put a few drops of diluted hydrochloric acid in a test tube.
- Add a little zinc powder to hydrochloric acid. What do you observe?

  Observation: ....

- Approach a burning match to the tube mouth. What do you observe?

  Observation: ....

- Put a few drops of hydrochloric acid to soduim carbonate salt, then pass the rising gas in a beaker containing clear lime water. What do you observe on the lime water?

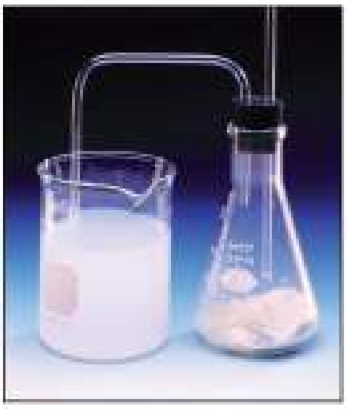
  Observation: ....

- Repeat the experiment using diluted sulfuric acid instead of hydrochloric acid.

Conclusion :

- What is the name of gas evolving in case of zinc? ....
- What is the name of gas evolving in case of carbonate? ....
- Express the reactions above using balanced symbolic

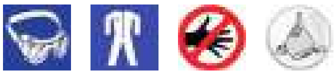
Reaction of zinc with HCl



CO_2 turbids limewater

Laboratory Activity : Titration of acid and base

Security and Safety



Purpose of the Activity

- ☑ Know the tools used to measure and transport the required volume of the desired solutions.
- ☑ Know the function of the phenolphthalein inhibitor in the experiment.
- ☑ Use the pH to know the types of solutions in terms of their acidic and base trait.

Acquired Skills

- ☑ Using tools – predicting – observing – concluding .

Materials

- ☑ 50 ml of HCl solution of unknown concentration – 100 ml of NaOH with 0.1 M concentration – 100 ml conical flask – three 100 ml flasks – funnel – burrete with carrier – phenolphthalein inhibitor – 10 ml pipette – pH metter.

Procedure :

- By using pH-meter identify the value of pH for HCl and NaOH.
- Fill the burrete with HCl solution.
- Take 10 ml from the NaOH solution by a pipette to the conical flask and then add drops of the phenolphthalein inhibitor. Place it at the bottom of the burrete. Place a white paper under the flask. What is the purpose for it?

  ....

- Start the titration by adding HCl drop by drop from the burrete while gently moving the flask.
- Why should the NaOH be moved during the titration process?

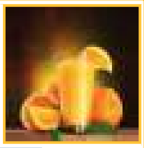
  ....

- Identify and record the approximate HCl needed to reach the equivalent point at which the pink color of the solution begins to disappear and then identify the pH value of the produced solution.
- Repeat the titration process three times with complete accuracy and then reach the average calculation of these three titrations. Why do the titration process repeat?

  ....

- If the value of pH of the produced solution is less than 7, is the titration process correct or not? ....
- What are the steps that should be taken to complete the titration process in the case there is a difference in the value of pH than 7.

  ....



Assessment Questions

First : Choose the correct answer :

1. The phosphoric acid H_3PO_4 is one of the .... acids
   A. Mono-proton B. Di-proton
   C. Tri-proton D. Poly-proton

2. The pH value of an acidic solution is ....
   A. 7 B. 5
   C. 9 D. 14

3. In the reaction of ammonia with the hydrochloric acid, the ammonium ion $(NH_4)^+$ is considered ....
   A. Conjugated acid B. Base
   C. Conjugated base D. Acid

4. One of the following acids is considered a strong acid ....
   A. Acetic acid B. Carbonic acid
   C. Nitric acid D. Citric acid

5. The pH value in which the color of phenolphthalein is red is ....
   A. 2 B. 4
   C. 6 D. 9

6. The conjugated acid HSO_4^- is ....
   A. HSO_4^+ B. SO_4^{-2}
   C. H_2SO_4 D. H^+

Second : Write the scientific term :

1. The substance that contains hydrogen and generates it when reacting with metals ....
2. Chemical substances that change color with the change of the median type ....
3. A method of expressing the degree of acidity or base with numbers from zero to 14 ....
4. A substance that has the ability to acquire (receive) a proton ....
5. A substance that has the ability to give a proton ....

Third : Think and infer at least one reason for each of the following :

1. Ammonia is considered a base although it does not contain a hydroxide group (OH^-) in its structure.

....

2. The hydrochloric acid is strong while the acetic acid is weak.

....

3. The pH value for ammonium chloride solution is less than 7.

....

4. Sulfuric acid has two types of salts.

....

Fourth : Answer the following questions :

1. Compare between the definition of acid and base in Arrhenius's theory and Bronsted-Lowry's theory. Mention examples and the equations expressing this.

....

2. Identify the acidic and the basic radicals of the following salts:

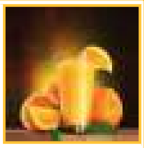
   Potassium nitrates – sodium acetates – copper sulfates – ammonium phosphates

....

3. Use the following radicals to form salts and then write the names of these salts:

$$NH_4^+ - Ca^{2+} - Ba^{2+} - Cl^- - SO_4^{2-} - NO_3^-$$

....



Unit Three Revision Questions

First : Choose the correct answer :

1. In the neutral median , the indicator that has a purple color is ....

   A. Litmus B. Phenolphthalein
   C. Orange methyl D. Blue bromothynol

2. The pH number for a base solution ....

   A. 7 B. 5
   C. 2 D. 8

3. Acids react with carbonate and bicarbonate salts and .... gas rises

   A. Hydrogen B. Oxygen
   C. Carbon dioxide D. Di-sulfur oxide

4. Dissolve 20 g of sodium hydroxide in an amount of water and complete the solution until 250 ml, the concentration is .... [Na = 23 , O = 16 , H = 1]

   A. 1 M B. 0.5 M
   C. 2 M D. 0.25 M

5. All of the following are mineral acids except ....

   A. Sulfuric acid B. Citric acid
   C. Phosphoric acid D. Hydrochloric acid

6. Which of the following salts form a solution of an alkaline affect on the litmus? ....

   A. NH_4Cl B. K_2CO_3
   C. $NaNO_3$ D. KCl

7. If one mole is dissolved from each of the following substances in one liter of water, which one of them has the largest effect in the vapor pressure of its solution? ....

A. KBr B. $C_6H_{12}O_6$

C. $MgCl_2$ D. $CaSO_4$

Second : Correct the underlined in the following statements :

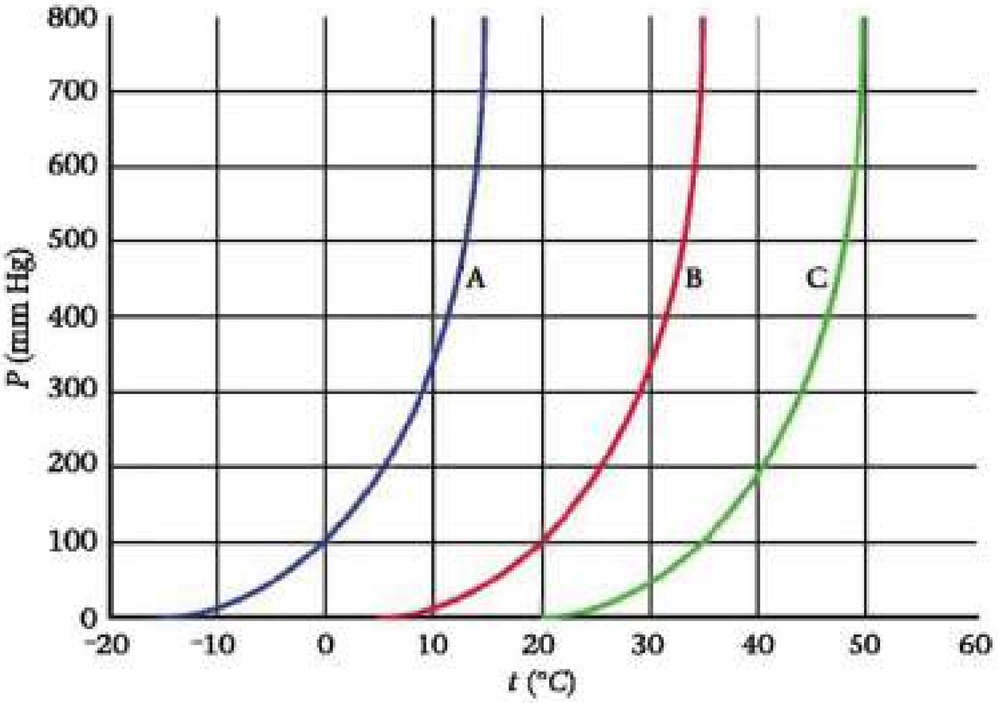
1. The color of phenolphthalein changes to the red color when placed in the neutral median. ....
2. Carbonic acid H_2CO_3 is a tri-proton acid. ....
3. The citric acid is considered a bi-proton acid. ....
4. Acid, according to Arrhenius, is the substance that dissolves in water to produce OH^- ion. ....
5. The solutions which have pH higher than 7 acids. ....
6. The diluted acids react with the active metals and produce oxygen gas. ....
7. The molal concentration of the solution that contains 0.5 M of solute in 500 g of solvent is 2 mol/kg. ....

Third : Write the scientific terminology :

1. The substances that dissolves in water to release the positive hydrogen ion. ....
2. A weak acid or base that changes color with the change of the pH value of the solution. ....
3. The substance that is produced after the acid losses a proton. ....
4. The number of moles of solutes in one kilogram of the solvents. ....
5. The mass of the solute in 100 g of the solvent at a certain temperature. ....

Fourth :

1. Study the diagram below that shows the change in the vapor pressure of three different solutions with temperature and answer the following questions:



A. Which of the solutions boils at 15°C knowing that the atmospheric pressure is (760 mmHg)

....

B. What is the boiling point of liquid B at standard conditions?

....

C. Arrange the solutions according to concentration.

....

Unit Four

General objectives of unit four :

By the end of this unit, the student will be able to :

- Identify the thermochemical equation.
- Identify the exothermic and endothermic reactions.
- Distinguish between the system and the surrounding.
- Compare between the types of different systems (opened – closed – isolated).
- Know the First Law of Thermodynamics.
- Infer that temperature is a measurement of the average of kinetic energies of the system's particles.
- Clarify the relationship between the system energy and its particle movement.
- Identify molar enthalpy (heat content).
- Apply the relationship that connects specific heat, heat capacity, and heat change.
- Calculate the absorbed energy or released energy of the system.
- Achieve Hess's law for the constant heat summation.

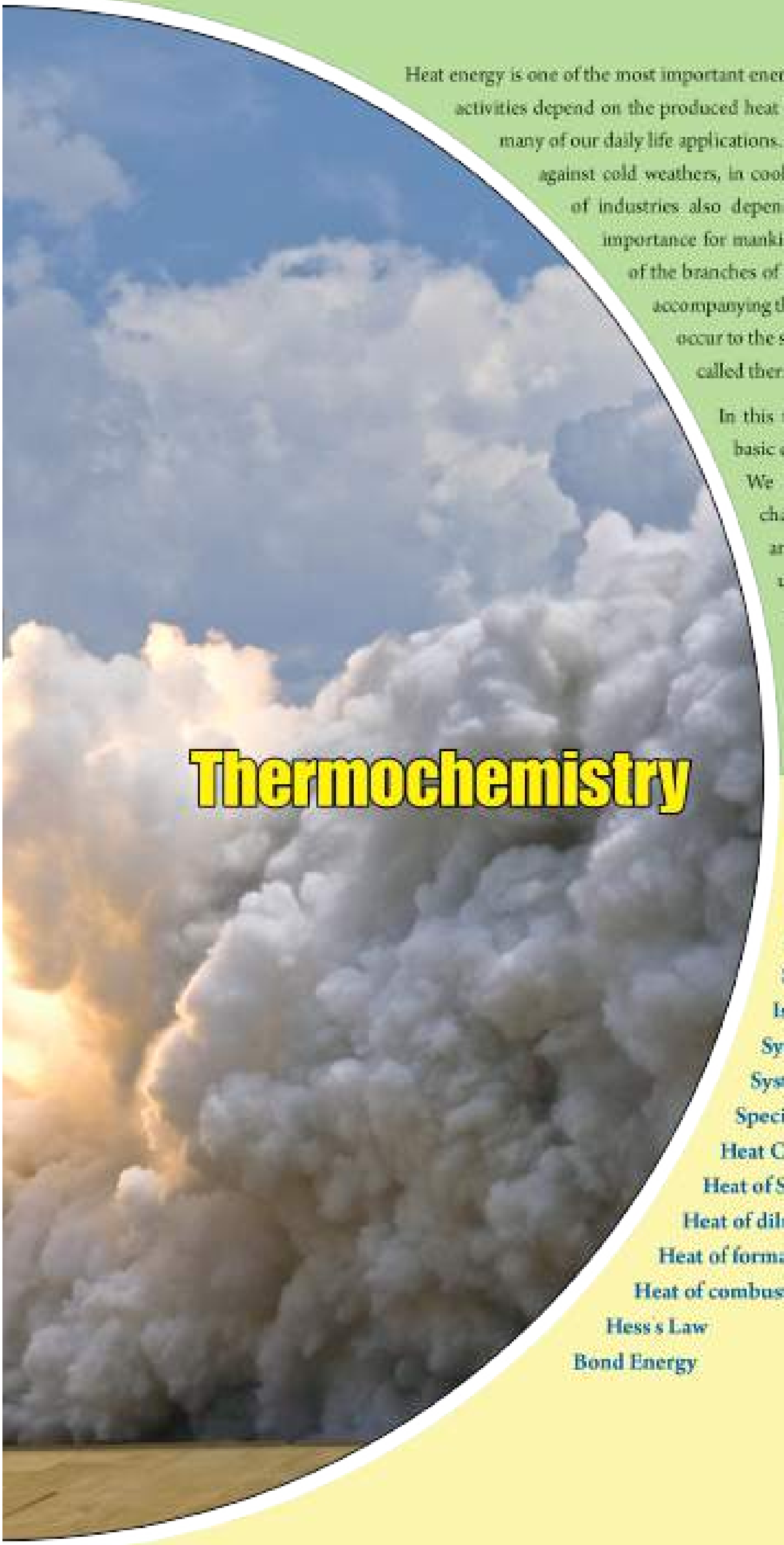
Unit Four lessons :

1 Heat Content

2 Forms of Changes in Heat Content

Involved Issues : Energy Problem

Thermochemistry



Heat energy is one of the most important energies for mankind. As all our different activities depend on the produced heat from burning food. We also use it in many of our daily life applications. It is used in households for warming against cold weathers, in cooking, and in drying. A large number of industries also depend on heat energy. Due to its vital importance for mankind, scientists were interested, in one of the branches of chemistry, to study the heat changes accompanying the chemical and physical changes that occur to the substance. This branch of science was called thermochemistry.

In this unit, we will deal with some of the basic concepts related to thermochemistry. We will also understand some of the changes that occur in the heat content and how to calculate these changes by using some methods. We will also use the calorimeter in measuring the heat changes accompanying the chemical and physical changes.

Key Terms :

- Thermochemistry
- System
- Surrounding
- Isolated System
- System Openend
- System Closed
- Specific Heat
- Heat Content
- Heat of Solution
- Heat of dilution
- Heat of formation
- Heat of combustion
- Hess s Law
- Bond Energy

Lesson One : Heat Content

Learning Outcomes

By the end of this lesson, you will be able to:

- ✓ Distinguish between the system and the surrounding.
- ✓ Compare between the types of different systems (opened – closed – isolated).
- ✓ Know the First Law of Thermodynamics.
- ✓ Know the thermo chemical equation.
- ✓ Identify the exothermic reactions and the endothermic reactions.
- ✓ Clarify the relationship between the system energies and its particle movement.
- ✓ Infer that temperature is a measurement of the median of movement energies of the system's particles.
- ✓ Identify molar enthalpy (heat content).
- ✓ Apply the relationship that connects specific heat, heat capacity, and heat change.

Basic concepts of thermochemistry

All the chemical and physical changes are accompanied by changes in energy. It is very important for all living organisms without energy we cannot move. The other various activities whether they are mental or muscular activities cannot be carried out without the need for the produced energy from burning sugars inside our bodies. We would also not be able to cook our food without heat energy resulting from the burning of natural gas. The science that deals with the study of energy and how it transfers is called thermodynamics. Scientists became interested in studying a branch of thermodynamics concerned with the heat effects that accompanying the chemical reactions and the physical changes. This branch came to be known as thermochemistry.

Law of Conservation of Energy

There are various forms of energy like: chemical energy, heat energy, light energy, electrical energy, and kinetic energy. However, through the classification of energy into different forms, you can imagine that each form is independent in itself from the rest of the forms. Inspite of this, there is a relationship between all the forms of energy as energy is converted from one form to another. And this leads us to the statement of the law of conservation of energy.

> Law of Conservation of Energy: the energy in any physical or chemical change can be neither created nor destroyed, but is transformed from one form to another.

But what is the relationship of a chemical reaction with energy?

Most chemical reactions are accompanied with changes in energy as most chemical changes either release energy or absorb energy. Energy exchange occurs between the reaction mixture and the surrounding. The reaction mixture is called the system and the parts of the universe outside the system with which the system interacts called the surrounding.

System: is part of the universe in which physical or chemical change occurs or it is the part of the substance chosen for study.

Surrounding: is the part outside the system and exchanges energy with it in the form of heat or work.

In case of chemical reactions, the system expresses the reactants and products. The system boundary may be a container, a flask or a test tube in which the reaction occurs, while the surrounding may be anything outside the reaction.

Types of Systems

- **Isolated System:** it does not exchange either energy or matter with its surroundings. i.e. system does not interact with its surroundings
- **Open System:** it freely exchanges matter and energy with its surrounding.
- **Closed System:** it exchanges energy (but not matter) with its surrounding in the form of heat or work.

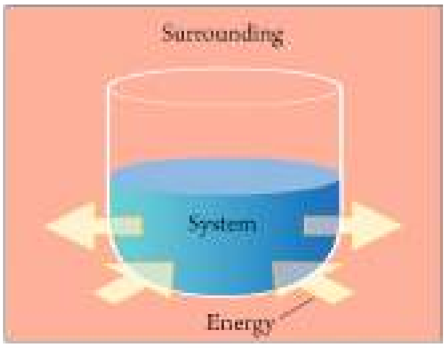


Figure (2) The system and its surrounding

Figure (3) Types of systems

First Law of Thermodynamics

Any change in the system's energy is accompanied by a similar change in the surrounding energy, but with an opposing sign so that the total energy remains constant.

$$\Delta E_{system} = - \Delta E_{surrounding}$$

First Law of thermodynamics: The total energy of an isolated system is constant even the system is changed from state to another.

Heat and Temperature

The flow of heat from one position to another depends on the difference in temperature between the two positions. So what is meant by temperature? And what is the relationship between temperature and the kinetic energy of its molecules?

Temperature: it is a measurement of the average kinetic energy of matter molecules and it indicates the hotness and coldness of an object.

molecules and atoms of substances are in continouse motion and vibration. However, they differ in their speed in the same substance. The system is formed from a group of molecules react with each other. Where , when the average kinetic energy of the molecules increases, the temperature also increases.

Heat is a form of energy ... it is considered as energy transferred between two bodies of different temperature.

Whenever the system absorb heat energy, the average speed of molecules increases. This expresses the kinetic energy of the molecules and leads to the rise of the system temperature, and vice versa.

i.e., there is a direct relationship between the system energy and the kinetic energy of its molecules.

Measuring units of quantity of heat

calorie

Is the quantity of heat needed to raise the temperature of 1 g of water by 1°C (15°:16°).

$$1 \text{ kilocalorie} = 1000 \text{ calorie}$$

Joule

Is the quantity of heat needed to raise the temperature of 1 g of water by $\frac{1}{4.184}$ °C

Enrichment Information

The Calorie is used when calculating the quantity of heat gained from food. The level of your Calorie consumption depends on the level of your activity. For example, if you spend a day working in the library, you consume approximately 800 Calories. While a marathon runner consumes approximately 1800 Calories to complete the race.

1 KCal = 1000 Cal

Specific Heat

Specific Heat: the quantity of heat required to raise the temperature of one gram of the substance by one degree Celsius.

The unit used in measuring specific heat is J/g°C specific heat differs accordingly with the type of substance. The substance that has large specific heat needs a large quantity of heat to rise its temperature. This needs a long time. It may also take a long time for the substance to lose this heat once more, in contrary of the substance that has lesser specific heat.

Substance	Aluminium	Carbon	Copper	Iron	Water (liquid)	Water (gas)
Specific heat (J/g.c°)	0.9	0.711	0.385	0.444	4.18	2.01

Table (1) Specific heat of some substances

Calculating the quantity of heat

The quantity of absorbed heat or released heat from the system can be calculated by using the following law:

$$q_p = m.\,c.\,\Delta T$$

As q_p expresses the quantity of heat at constant pressure, m is the mass, c is the specific heat, and ΔT is the difference of temperature. It is calculated from the relationship ($\Delta T = T_2 - T_1$), as T_1 is the initial temperature, while T_2 is final temperature.

The Calorimeter

The calorimeter provides an isolated system that allows us to measure the change in temperature of the isolated system. As it prevents the lose or gain of any quantity of heat or substance with its surrounding. The calorimeter also allows us to use a certain amount of substance where heat exchange occurs with it. This substance is most likely water due to its increase of specific heat, which allows it to gain or lose a large quantity of heat. The change in temperature is calculated by calculating the difference between the final temperature and the initial temperature ΔT.

There are other types of calorimeters called bomb calorimeters used to measure the heat of combustion of some substances. In bomb calorimeters, reaction occurs with a known amount of substance needs to be burned in the excess amount of oxygen under constant atmospheric pressure. It is placed in an isolated steel container called the steel bomb. The substance is ignited using an electric wire. The steel bomb is surrounded by an identified amount of water.

Calorimeter Components

The calorimeter is constructed of an insulted container, a thermometer, and a stirrer. A liquid is placed inside it, which is most likely to be water.

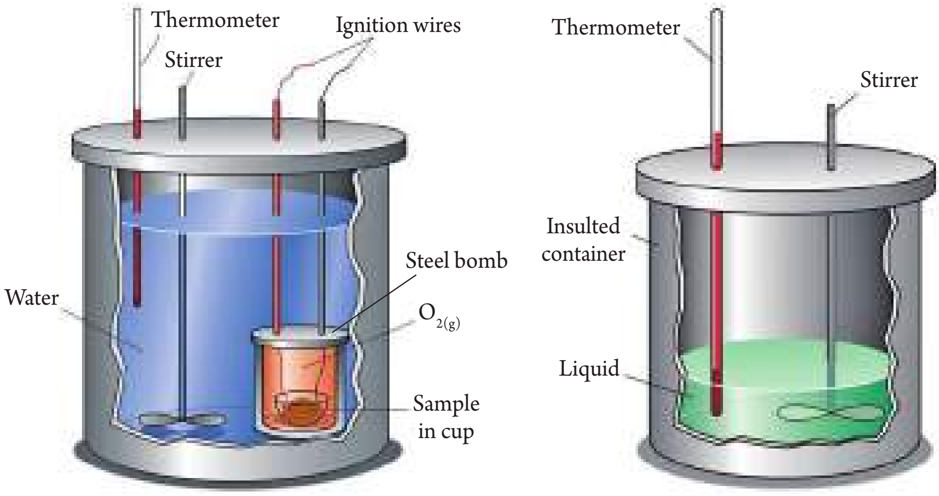


Figure (5) Calorimeter

Think and Infer

Is specific heat constant for one substance inspite of the difference in the amount of this substance or its physical state?

The multiplication product of mass (m) in specific heat (c) is known as heat capacity (c).

Example:

Dissolve one mole of ammonium nitrates in an amount of water. Complete the solution volume to 100 ml of water. You notice that the temperature decreases from 25°C to 17°C Calculate the quantity of absorbed heat.

Solution:

In diluted solutions, the mass of a millimeter of water is calculated to equal one gram because the water density = 1 g / ml.

$q = 100\ g \times 4.18\ J/g°C \times (17 - 25)°C = -3344\ J$

$q = -3.344\ kJ / mol$

Heat Content

Each chemical substance differs in the number and type of atoms included in its structure. It also differs in the type of bond between its atoms than the other substances. Therefore, each substance has a specified amount of energy called the internal energy. This amount is the summation of a number of types of energy stored inside the substance.

- **Stored chemical energy in the atom:** is represented in the electron energy in the energy levels. It is the summation of kinetic energy and potential energy of the electron in the energy level.

- **Stored chemical energy in the molecule:** the chemical energy in the molecule is found in the chemical bonds between its atoms whether they are covalent bonds or ionic bonds.
- **Intermolecular forces:** the attraction force between the molecules is known as the Van der Waals attraction force. It is considered a potential energy. There are other forces between the molecules like the hydrogen bonds. These forces depend on the nature of molecules and their polarity.

From the previous, we can clarify that:

The substance stores an amount of energy that is produced from the electron energy in the energy levels of the atom, the energy of chemical bonds, and the energy of attraction between the molecules. The sum of these energies found in a mole of a substance is called the heat content of the substance or the molar enthalpy.

> Heat content of a substance (H) (molar enthalpy): the sum of stored energies in one mole of a substance.

Molecules of different substances differ in the type of atoms, their number, or the types of bonds in them, it is normal that the heat content differs for the various substances. It is practically not possible to measure the heat content or the stored energy in a certain substance. However, what we can measure is the change occurring to the heat content during the different changes that occur to the substance.

> Heat content change (ΔH): the difference between the sum of the heat content of the products and the sum of the heat content of the reacting substances.

i.e. : heat content change = heat content of the products – heat content of the reactants

$$\Delta H = \Sigma H_{products} - \Sigma H_{reactants}$$

ΔH° Standard Heat Content

Scientists have agreed on the comparison of values of the different reactions under one standard conditions, which are:

- Pressure that equals atmospheric pressure 1 atm.
- Room temperature 25°C.
- Solution concentration 1 M.

Scientists have considered that the heat content for the element = zero.

For a process at constant pressure if Δq_p is the quantity of heat absorbed or released, and n is the number of moles, then $\frac{\Delta q_p}{n} = \Delta H$

It is possible to classify the heat changes accompanying the chemical reactions into two types:

First: Exothermic Reactions

The reactions that produce heat to the surrounding and its temperature increases.

An example of an exothermic reaction is the reaction of hydrogen gas with oxygen gas to form water. As 1 mol of hydrogen gas (H_2) reacts with ½ mol of oxygen gas (O_2) to form 1 mol of water (H_2O). A quantity of heat = 285.8 kJ / mol is released , as in the following equation:

$$H_{2(g)} + \frac{1}{2} O_{2(g)} \longrightarrow H_2O_{(l)} + 285.8 \text{ kJ/mol}$$

From the previous equation, we conclude the following:

- Heat transfers from the system to the surrounding , which leads to decrease the temperature of the system and increase the temperature of the surrounding.
- The sum of heat contents for the products is less than the sum of heat contents of reactants. According to the law of energy conservation, the reaction will produce an amount of heat to compensate the products.
- The change in the heat content (ΔH) has negative sign.

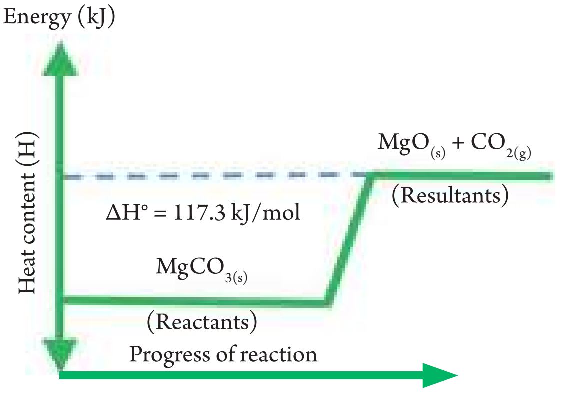
Second: Endothermic Reactions

They are the reactions that absorb heat from the surrounding and its temperature decreases. An example of an endothermic reaction is thermal decomposition of magnesium carbonates ($MgCO_3$) into magnesium oxide (MgO) and carbon dioxide (CO_2). As every 1 mol of ($MgCO_3$) needs to absorb 117.3 kJ/mol of energy to give 1 mol of (MgO) and 1 mol of (CO_2), as in the following equation:

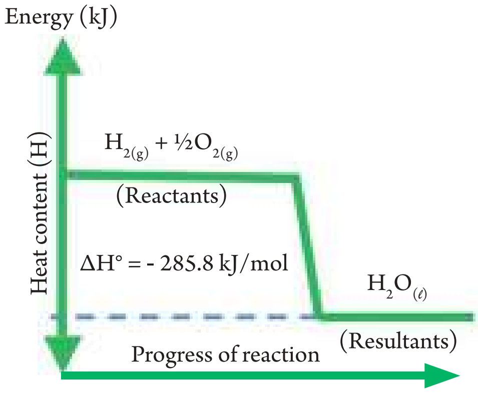
$$MgCO_{3(s)} + 117.3 \text{ kJ/mol} \longrightarrow MgO_{(s)} + CO_{2(g)}$$

From the previous equation, we reach the following:

- Energy transfers from the surrounding to the system so that the system absorbs heat and the surrounding loses heat.
- The sum of heat contents for the products is higher the sum of the heat contents for the reactants.
- The heat content change (ΔH°) has positive sign.



▲ **Figure (7) Diagram of endothermic reaction of heat**



▲ **Figure (8) Diagram of exothermic reaction of heat**

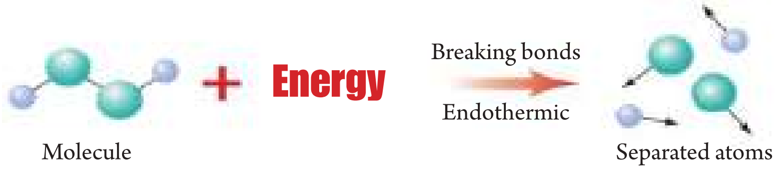
Go Further

For more knowledge about this topic you can refer to the Egyptian Knowledge Bank (EKB) through the opposite link.

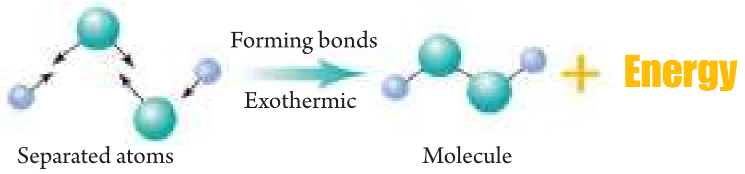
Heat Content and Bond Energy

During the chemical reaction the bonds in the reactants are breaking and new bonds in the products are formed as the chemical bond stores chemical potential energy.

- During the breaking of the bond, an amount of energy is absorbed from the surrounding until the bond is broken.



- During the formation of the bond, energy is released to the surrounding (so the temperature of the surrounding increases).



Bond Energies: energy must be absorbed to break the bond or energy is released when the bond is formed in one mole of the substance.

Each bond energy differs accordingly to the type of compound or its physical state. Therefore, scientists agreed to use the average bond energy instead of the bond energy. Table (2) shows the average energy for some bonds:

Bond	Average bond energy kJ/mol
H — H	432
C — O	358
C ═ O	803
O — H	467
O ═ O	498

Bond	Average bond energy kJ/mol
C — C	346
C ═ C	610
C ≡ C	835
C — H	413
Si — H	318

▲ **Table (2) Average energy for some bonds**

- When the released energy from bonds formation in the products is larger than the absorbed energy to break reactant , an energy is released equal to the difference in energy in the two processes. And the reaction is exothermic, and $\Delta H°$ is negative.
- A larger energy is absorbed when breaking the bonds of the reactants than when released when forming bonds in products. The reaction is endothermic and $\Delta H°$ is positive.

Example:

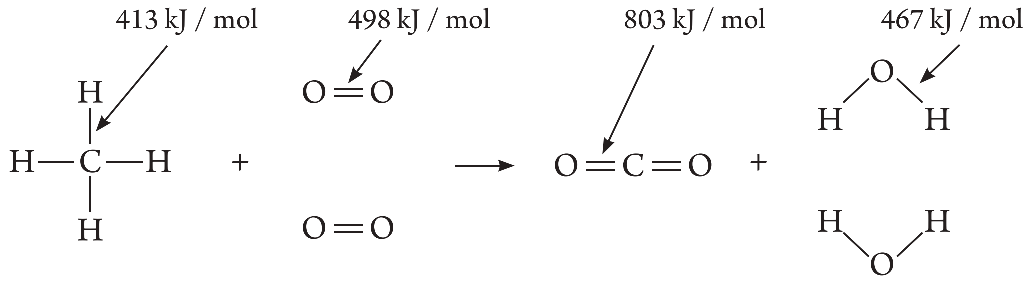
Calculate the heat of the following reaction and determine if the reaction is exothermic or endothermic.

$$CH_{4(g)} + 2O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(g)}$$

Knowing that bond energy is estimated by the unit kJ / mol as follows:

(C ═ O) 803 , (O — H) 467 , (C — H) 413 , (O ═ O) 498

Solution:



The energy required to break reactant bonds = [4 × (C — H)] + [2 × (O ═ O)]

= [4 × 413] + [2 × 498] = 2648 kJ

Released energy from the formation of bonds in the products = [2 × (C ═ O)] + [2 × 2 (O — H)]

= [2 × 803] + [2 × 2 × 467] = 3474 kJ

$(\Delta H) = (+2648) + (-3474) = -826$ kJ/mol

And therefore, the reaction is exothermic because the sign is negative.

Thermochemical Equation

Notice the following equation, and then infer what is meant by the thermochemical equation, and what are its conditions ?

$$H_{2(g)} + \frac{1}{2} O_{2(g)} \longrightarrow H_2O_{(g)} + 242 \text{ kJ/mol}$$

Thermochemical equation: a symbolical chemical equation that includes the heat change accompanying the reaction, and is represented in the equation as one of the reactants or products.

The thermochemical equation should have the following conditions:

- It must be balanced. The coefficients in the balanced thermochemical equation represent the number of moles of the reactants and products and do not represent the number of molecules. Therefore, we can write these coefficients as fractions and not necessarily real numbers, as in the following example.

$$H_{2(g)} + \frac{1}{2} O_{2(g)} \longrightarrow H_2O_{(\ell)} + 285.8 \text{ kJ/mol}$$

- The physical state of the reactants or the products must be mentioned. Some symbols that represent this state are used like: aq , ℓ , g , s due to the heat content changes with the change of the physical state of the substance, which, in turn, effects the value of the heat change. The following example reveals this:

$$H_{2(g)} + \frac{1}{2} O_{2(g)} \longrightarrow H_2O_{(\ell)} \qquad \Delta H^\circ = -285.8 \text{ kJ/mol}$$

$$H_{2(g)} + \frac{1}{2} O_{2(g)} \longrightarrow H_2O_{(g)} \qquad \Delta H^\circ = -242 \text{ kJ/mol}$$

- It clarifies the value and sign of the change in the heat content (ΔH°) of the chemical reaction or the physical changes, i.e. to have a positive or negative sign. The positive sign means the reaction is endothermic, while the negative sign means that the reaction is exothermic, as in the following examples.

$$H_2O_{(s)} \longrightarrow H_2O_{(\ell)} \qquad \Delta H^\circ = +6 \text{ kJ/mol}$$

$$CH_{4(g)} + 2O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(\ell)} \qquad \Delta H^\circ = -890 \text{ kJ/mol}$$

- When multiplying or dividing the two ends of the equation with a certain numerical coefficient, the same operation must be conducted on the change value in the heat content, as follows:

$$H_2O_{(s)} \longrightarrow H_2O_{(\ell)} \qquad \Delta H^\circ = +6 \text{ kJ/mol}$$

$$2H_2O_{(s)} \longrightarrow 2H_2O_{(\ell)} \qquad \Delta H^\circ = 2 \times 6 \text{ kJ/mol} = 12 \text{ kJ/mol}$$

- The direction of the heat content can be inversed. In this case, the sign of the heat content ΔH is changed as in the following example:

$$H_2O_{(s)} \longrightarrow H_2O_{(\ell)} \qquad \Delta H^\circ = +6 \text{ kJ/mol}$$

$$H_2O_{(\ell)} \longrightarrow H_2O_{(S)} \qquad \Delta H^\circ = -6 \text{ kJ/mol}$$

Lesson Two : Forms of Changes in Heat Content

Learning Outcomes

By the end of this lesson, you will be able to:

- ✓ Calculate the absorbed heat and the released heat from the system.
- ✓ Infer the change in the heat content of the system from the averages of the heat content.
- ✓ Achieve Hess's law for heat summation.

The calculation of change in heat content is of great importance. As the understanding of the change in heat content accompanying the burning of different fuels helps when designing engines to know which type of fuel is more suitable for these engines. It also helps firemen in identifying the amount of heat accompanying the burning of different materials. This helps them to choose the most suitable method to fight the fire. The forms of change in the heat content differ according to the type of physical or chemical change occurring.

Figure (9) Stored chemical energy in fuel transforms into heat energy and work

Heat Changes Accompanying Physical Changes

Examples of a physical change include dissolving and diluting. We will study in detail the heat changes accompanying each of them:

Standard Heat of Solution

> Standard heat of solution ΔH°_{s} : the quantity of absorbed or released heat when dissolving one mole of the solute in a certain amount of the solvent to gain a saturated solution under standard conditions.

When dissolving ammonium nitrates (NH_4NO_3) in water, the temperature of the solution decreases. Solution, in this case, is an endothermic and is expressed by the following equation:

$$NH_4NO_{3(s)} \longrightarrow NH^{+}_{4(aq)} + NO^{-}_{3(aq)} \qquad \Delta H^{\circ}_{s} = +25.7 \text{ kJ / mol}$$

When dissolving sodium hydroxide (NaOH) in water, the solution's temperature rises and, is solution exothermic solution is expressed by the following equation:

$$NaOH_{(s)} \longrightarrow Na^{+}_{(aq)} + OH^{-}_{(aq)} \qquad \Delta H^{\circ}_{s} = -51 \text{ kJ / mol}$$

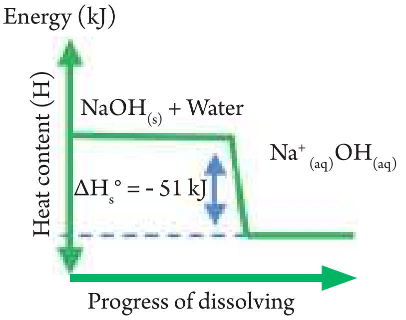


Figure (10) Sodium hydroxide exothermic solution

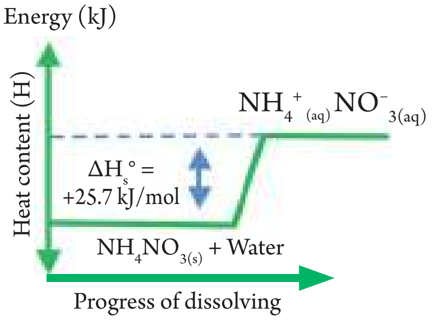
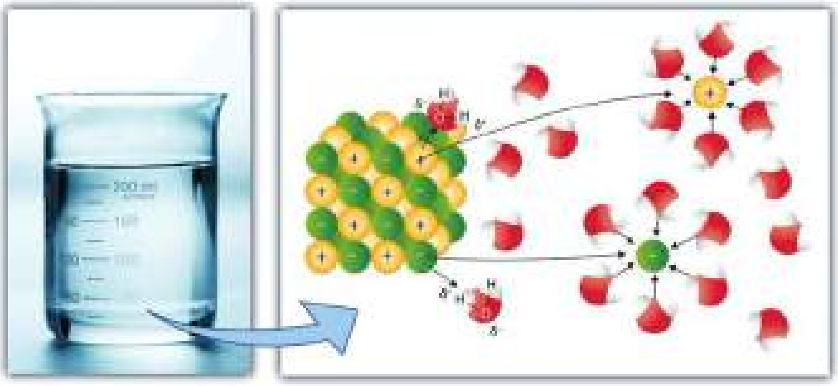


Figure (11) Ammonium nitrates endothermic solution

The heat of solution can be explained in the following steps:

- Separating solvent molecules: an endothermic process that requires energy to overcome the attraction force between the solvent's molecules, and is denoted by ΔH_1
- Separating solute molecules: it is also an endothermic process that requires energy to overcome the attraction force between the solute's particles, and is denoted by ΔH_2
- Dissolving process: it is an exothermic process as energy is released when solvent particles are combined with solute molecules, and is denoted by ΔH_3 (It is called hydration energy, if the solvent is water).

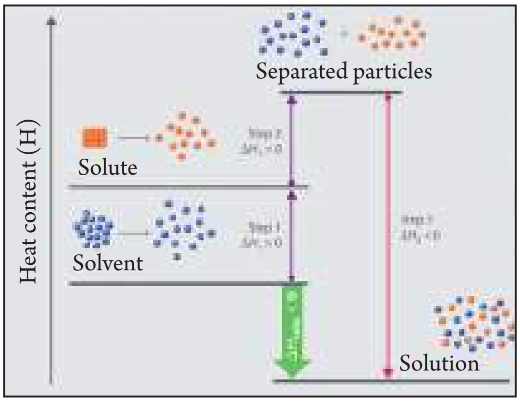


▲ **Figure (12) soulibility**

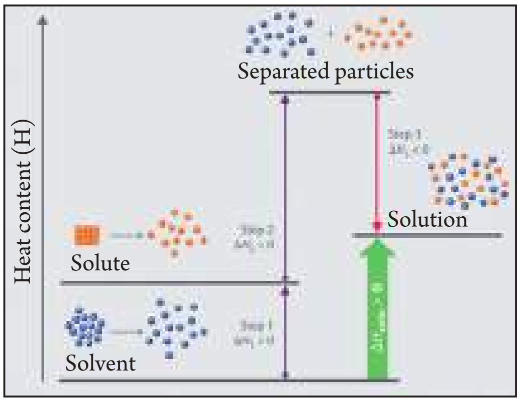
The value of heat of solution ΔH_s depends on the sum of these processes:

- If $\Delta H_1 + \Delta H_2 > \Delta H_3$ the solution is endothermic
- If $\Delta H_1 + \Delta H_2 < \Delta H_3$ than the solution is exothermic

The following graph shows an endothermic solution and an exothermic solution.



▲ **Figure (13) Diagram of an endothermic solution**



▲ **Figure (14) Diagram of an exothermic solution**

Enrichment Information

Previously prepared sachets are used as cold fomentations. These sachets contain two layers separated by a thin membrane. In one layer, there is ammonium nitrate and in the other layer, there is water. When needed, pressure is applied on the fomentation and the thin membrane is teared. This allows the two substances to mix and thus, the temperature in the sachet decreases due to it being an endothermic solution. Heated fomentation sachets are also available as they contain calcium chloride and water. In this case, the solution is exothermic.

The heat of solution can be calculated by using the relation: $q = m \cdot c \cdot \Delta T$

- In diluted solutions, the solution's mass (m) can be expressed by the volume because the denisty of water in normal conditions equals 1.

- The specific heat of the solution can be considered equal to the specific heat of water 4.18 J/g°C
- If the solution has a 1 molar concentration (1 mol / L) , i.e. the amount of solute (1 mol) and the volume of the produced solution (1 L), then the amount of released or absorbed energy, in this case, is called the molarity heat of solution.

> Molar heat of solution: the heat change from dissolving one mole from the solute to form a liter of the solution.

Standard Heat of Dilution

Study the following two examples, as they reveal that the difference of heat of solution is due to the difference of the amount of solvent. Then try to reach how dilution effects change in the heat content.

$$NaOH_{(s)} + 5H_2O_{(\ell)} \longrightarrow NaOH_{(aq)} + 37.8\ kJ/mol$$

$$NaOH_{(s)} + 200H_2O_{(\ell)} \longrightarrow NaOH_{(aq)} + 42.3\ kJ/mol$$

In a concentrated solution, the solute ions get closer to each other. When adding another amount of solvent (dilution), the ions move away from one another. This needs an energy called ion separation energy, it is an absorbed energy. By increasing the number of molecules of the solvent, the ions are attached to a greater number of its molecules, and an amount of heat is released. The change in the heat content is the sum of those two operations. The standard heat of dilution can be identified as:

> Standard heat of dilution ΔH°_{dil} : the quantity of released or absorbed heat for each one mole when diluting the solution from a high concentration to another lower concentration with the condition of being in its standard state.

Heat Changes Accompanying Chemical Changes

We will deal with the heat changes accompanying some chemical changes like:

Standard Heat of Combustion

Combustion is a rapid reaction of a substance with oxygen. The complete combustion of elements and compounds produces a large amount of energy in the form of heat or light. The released energy is known as the combustion heat (ΔH_c). The standard heat of combustion is known as follows:

> Standard heat of combustion ΔH°_{c} : the quantity of released heat when one mole of substance is completely combusted in excess amount of oxygen under standard conditions.

Examples of combustion reactions that we use in our everyday life include the combustion of stove gas (it is a mixture of propane C_3H_8 and butane C_4H_{10}) with the atmospheric oxygen to produce a large amount of heat, which is used in cooking food and has other usages. The following equation represents the complete combustion of propane gas in the presence of oxygen gas:

$$C_3H_{8(g)} + 5O_{2(g)} \longrightarrow 3CO_{2(g)} + 4H_2O_{(g)} + 2323.7\ kJ/mol$$

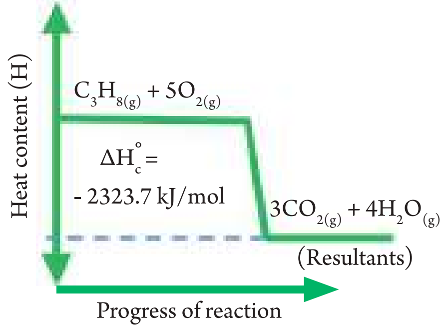


Figure (15) **Energy diagram for combustion of propane**

One of the important combustion reactions is the complete combustion of glucose $C_6H_{12}O_6$ inside the bodies of living organisms in the presence of oxygen to provide the organisms with the necessary energy to perform their vital functions, as in the following equation:

$$C_6H_{12}O_{6(s)} + 6O_{2(g)} \longrightarrow 6CO_{2(g)} + 6H_2O_{(g)}, \ \Delta H_c^\circ = -2808 \text{ kJ/mol}$$

Standard Heat of Formation

The heat change accompanying the formation of the compound from its elements is called the heat of formation (ΔH_f). The standard heat of formation can be known as follows:

> Standard heat of formation ΔH_f° : the quantity of released or absorbed heat when one mole of a compound is formed from its elements where these elements are in its standard state.

Relation Between Heat of Formation and Stability of the Compound

The heat of formation of a compound is its heat content. Through the results of experiments, scientists have observed that the compounds that have negative heat of formation are more stable at room temperature and do not tend to dissociate because its heat content is small. In contrary to the compounds that have positive heat of formation, as it tends to spontaneously dissociate to its elements at room temperature. Most reactions move in the direction of the formation of the most stable compounds.

Using the standard heat of formation (H_f°) to calculate the change in the heat content

The standard heat of formation for all elements are zero at the standard conditions of pressure and temperature, i.e. when the temperature is 25°C and the pressure is 1 atm.

As the change in the heat content can be calculated from the following relation:

(ΔH) = the sum of heats content of the products – the sum of heat contents of the reactants

The change in the heat content of compounds can also be calculated by using the heat of formation from the following relation:

(ΔH) = the sum of the heat of formation of the products – the sum of the heat formation of the reactants

Example:

If the heat of formation of methane is -74.6 and carbon dioxide is -393.5 and water is -241.8 kJ/mol, calculate the change in the heat content of the reaction shown in the following equation:

$$CH_{4(g)} + 2O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(g)}$$

Solution:

(ΔH_f) = the sum of the heat of formation of products – the sum of the heat of formation of reactants

$$= (CO_2 + 2H_2O) - (CH_4 + 2O_2)$$

$$= [(-393.5) + (2 \times -241.8)] - [(-74.6) + (2 \times 0)] = -802.5 \text{ kJ/mol}$$

Hess's Law of Constant heat summation

Scientists usually refer to using indirect methods to calculate heat of reaction. This is due to a number of reasons such as:

- The mixture of reactants or products with other substances.
- Some reactions occur very slowly and needs a long time like the formation of rust.
- The presence of danger when measuring heat of reaction by an experimental method.
- Difficulties when measuring heat of reaction in normal conditions of pressure and temperature.

In order to measure heat change of reactions like these, scientists used Hess's Law.

> Hess's Law: heat of reaction is a constant amount in standard conditions, whether the reaction is carried out in one step or a number of steps.

The algebraic formula for Hess's law can be expresses as follows: $\Delta H = \Delta H_1 + \Delta H_2 + \Delta H_3 ...$

The importance of this law is due to the ability to calculate the change in the heat content ($\Delta H°$) of the reactions that can not be measured in a direct way. This is achieved by using other reactions in which the heat of each reaction can be measured. The concept of Hess's law can be clarified through the following two examples:

Example (1) :

In the light of your understanding to Hess's law , calculate the heat of forming carbon monoxide CO in the following two equations :

(1) $C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)}$ $\Delta H_1 = -393.5$ kJ/mol

(2) $CO_{(g)} + \frac{1}{2} O_{2(g)} \longrightarrow CO_{2(g)}$ $\Delta H_2 = -283.3$ kJ/mol

Solution:

By subtracting the two equations algebracally :

$$C_{(s)} + O_{2(g)} - CO_{(g)} - \frac{1}{2} O_{2(g)} \longrightarrow CO_{2(g)} - CO_{2(g)}$$

$$\Delta H = \Delta H_1 - \Delta H_2 = -393.5 - (-283.3) = -110.5 \text{ kJ/mol}$$

By transferring $CO_{(g)}$ from the left side to the right side of the equation :

$C_{(s)} + \frac{1}{2} O_{2(g)} \longrightarrow CO_{(g)}$ $\Delta H = -110.5$ kJ/mol

Example (2) :

Calculate the combustion of nitric oxide NO with respect to the following equation :

$$NO_{(g)} + \frac{1}{2} O_{2(g)} \longrightarrow NO_{2(g)}$$

In terms of the two equations next :

(1) $\frac{1}{2} N_{(2)} + \frac{1}{2} O_{2(g)} \longrightarrow NO_{(g)}$ $\Delta H = +90.29$ kJ/mol

(2) $\frac{1}{2} N_{2(g)} + O_{2(g)} \longrightarrow NO_{2(g)}$ $\Delta H = +33.2$ kJ/mol

Solution:

By subtracting equation (1) from (2) :

$\frac{1}{2} N_{2(g)} + O_{2(g)} - \frac{1}{2} N_{2(g)} - \frac{1}{2} O_{2(g)} \longrightarrow NO_{2(g)} - NO_{(g)}$ $\Delta H = \Delta H_2 - \Delta H_1$

$\frac{1}{2} O_{2(g)} \longrightarrow NO_{2(g)} - NO$ $\Delta H = (33.2 - 90.29)$ kJ/mol

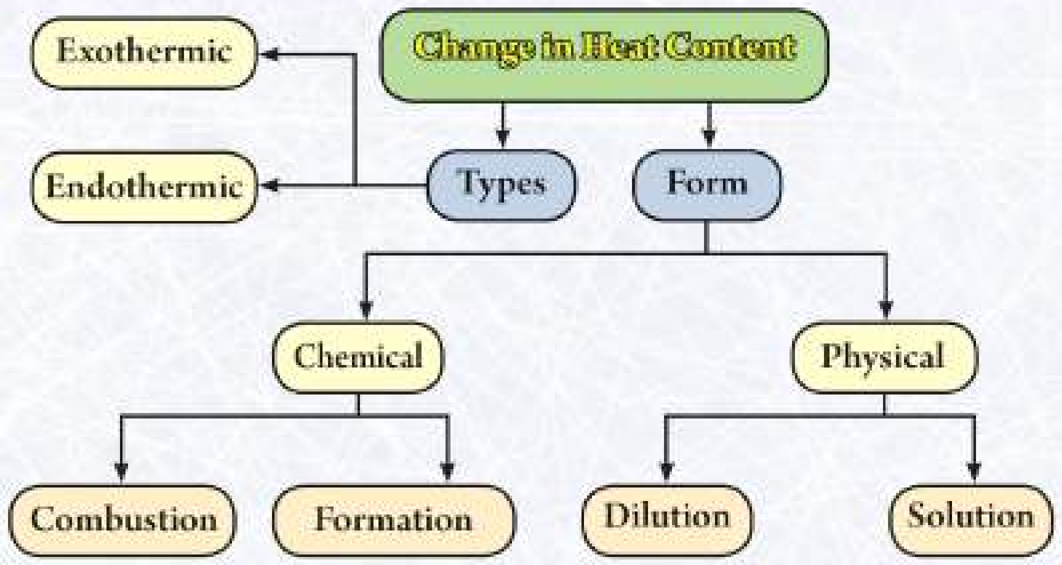
By transferring $NO_{(g)}$ to the left side with different sign :

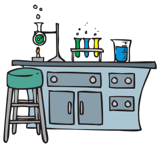
$NO_{(g)} + \frac{1}{2} O_{2(g)} \longrightarrow NO_{2(g)}$ $\Delta H = -57.09$ kJ/mol

Basic Terminology in Unit Four

- **Thermochemistry:** a branch of thermodynamics. A science that deals with the study of heat changes accompanying chemical reaction and physical changes.
- **First Law of thermodynamics:** The internal energy of an isolated system is constant and energy can be transformed from one form to another.
- **Heat content of a substance:** the sum of stored energies in one mole of a substance.
- **Standard heat of solution:** the amount of absorbed or released heat when dissolving one mole of the solute in a certain amount of the solvent to gain a saturated solution under standard conditions.
- **Standard heat of dilution:** the amount of released and absorbed heat for each one mole when diluting the solution from a high concentration to another lesser concentration with the condition of being in its standard state.
- **Standard Heat of Combustion:** Combustion is a rapid unity operation of a substance with oxygen. The complete combustion of some elements and compounds produces a large amount of energy in the form of heat or light. The released energy is known as the combustion energy.
- **Standard heat of formation:** the amount of released and absorbed energy when forming one mole of a substance from its elementary substance on condition that this substance is in its standard condition.
- **Hess's Law:** heat of reaction is a constant amount in standard conditions, whether the reaction is conducted in one step or a number of steps.

Organizational Chart of Unit Four





Lesson One : Heat Content

Laboratory Activity : Exothermic Reactions

Security and Safety

Purpose of the Activity

- ☑ Understand the exothermic reactions.

Acquired Skills

- ☑ Hypothesizing – predicting – observing – recording data – concluding – analyzing data.

Materials

- ☑ Calcium oxide – balance – metal container – piece of butter.

Procedure :

- Determine mass of 20 g of calcium oxide and place it in a metal container.
- Place a piece of aluminum foil on the surface of calcium oxide so that it is adjacent to it.
- Add an amount of water on the calcium oxide.
- Put a piece of butter on top of the aluminum foil.
- Observe what happens to the piece of butter.

Observation: ....
....

Analyze data :

- Is this reaction considered exothermic or endothermic and why?

....

Conclusion :

....
....
....

Unit 4
Activities and Assessment Questions

Laboratory Activity : Endothermic Reactions

Security and Safety

Purpose of the Activity

☑ Understand the exothermic reactions.

Acquired Skills

☑ Hypothesizing – predicting – observing – recording data – concluding – analyzing data.

Materials

☑ Conical flask – sodium carbonates – ammonium chloride – thin piece of wood

Procedure :

- Determine mass of 53 g of sodium bicarbonates and put it in a conical flask.
- Place the flask on a thin piece of wood that is wet and observe what happens.

Observation: ....

....

- Repeat the previous steps using ammonium chloride instead of sodium bicarbonates.

Analyze data :

- Is this reaction considered exothermic or endothermic and why?

....

Conclusion :

....

....

Assessment Questions

First : Choose the correct answer :

1. Measuring unit of specific heat is the ....

   A. Joule B. J / mol

   C. J / K° D. J / g°C

2. Which of the following substances has a larger heat capacity ....

   A. 1 g water B. 1 g iron

   C. 1 g aluminum D. 1 g mercury

3. In exothermic reactions ....

   A. Heat moves to the system from the surrounding

   B. Heat moves from the system to the surrounding

   C. Heat does not move from or to the system

   D. Heat moves from and to the system at the same time

4. In the isolated system ....

   A. Exchange occurs between heat and the substance with the surrounding

   B. Exchange of heat occurs with the surrounding

   C. Exchange of the substance occurs with the surrounding

   D. Exchange of heat or substance does not occur with the surrounding

5. What is meant by the standard conditions of the reaction ....

   A. Under 1 atm pressure and temperature of 0°C

   B. Under 1 atm pressure and temperature of 25°C

   C. Under 1 atm pressure and temperature of 100°C

   D. Under 1 atm pressure and temperature of 273°C

Second : Various Questions :

1. If you knew that the specific heat for platinum = 0.133 J / g°C and titanium = 0.528 J / g°C and zinc = 0.388 J / g°C So if we have a sample with a mass of 70 g from each metal at room temperature, which metal has the first increase in temperature when heated under the same conditions? Mention the reasons.

   ....

2. Explain how the breakage and formation of the bond accompanying the chemical reaction specifies the kind of reaction whether it is endothermic or exothermic.

   ....

3. What does it mean?

   A. The average bond energy of C - C is 346 KJ / mol

   ....

   B. Specific heat of water = 4.18 J / g.°C

   ....

Third : Think and Infer :

1. Water causes a moderate climate in coastal areas in both winter and summer. Explain your answer.

   ....

2. In a medical thermometer, is the system opened or closed? And how did this system transform into an isolated system?

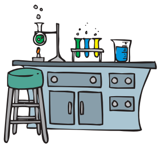
   ....

3. When is the value of change of heat content of the reaction and heat of combustion equal?

   ....

4. Farmers in cold areas spray fruit trees with water.

   ....



Lesson Two : Forms of Changes in Heat Content

Laboratory Activity : Heat of Solubility

Security and Safety

Purpose of the Activity

- ☑ State the heat changes accompanying the solubility process.

Acquired Skills

- ☑ Hypothesizing – predicting – observing – recording data – concluding – analyzing data.

Materials

- ☑ A covered foam cup – an uncovered foam cup – alcoholic thermometer – balance – distilled water – calcium chloride.

Procedure :

- Determine the mass of a covered foam cup and place in it 50 ml of distilled water and then place the cover. Identify the mass of the cup once again.
- Place the first cup inside a second larger cup while placing some cotton between them as an insulator. Record the temperature of water using an alcoholic thermometer.
- Identify the mass of 4 g of calcium chloride and then add it to the water while stirring. State the temperature of the solution after making sure the substance is completely dissolved.
- Notice the change in water temperature after the dissolving of calcium chloride.

Observation: ....

....

Recording data :

- Record the data in the following table and then explain it.

Procedure	Value
Mass of empty beaker	....
Mass of beaker and water	....
Water mass	....
Water temperature	....
Calcium chloride mass	....
Solution temperature	....
Temperature change	....

Analyzing Data :

- What is the reason for change in water's temperature after the dissolving of calcium chloride?

....

- Calculate the released or absorbed heat when calcium chloride dissolves.

....

- Calculate the number of moles of calcium chloride and then calculate the change in the heat content.

....

- Does the change in water temperature differ if dissolved 6 g of calcium chloride?

....

Conclusion :

- Calculate the change in the heat content accompanying the dissolving of 4 g of calcium chloride in water.

....

Assessment Questions

First : Write the scientific terminology :

1. The quantity of released or absorbed heat when dissolving one mole of a solute in a certain amount of solvent to gain a saturated solution. ....
2. The bondage of dissociated ions in water. ....
3. The quantity of released and absorbed heat when forming one mole of the substance from its primary elements on condition that these substances are in their standard condition. ....
4. The quantity of released heat from a complete combustion of one mole of the substance in an excess of oxygen. ....

Second : Write the scientific explanation for each of the following :

1. When writing the thermal chemical equation, the physical state of the accompanying substances in the reaction and the substance produced from it must be mentioned.
2. Using Hess's law in calculating the heat formation of carbon dioxide.
3. The solubility process is accompanied by a heat change.
4. The formation heat has a strong relationship with the stability of compounds

Third : Various Questions :

1. Calculate the standard change in the heat content for the following reaction:

$$H_2S_{(g)} + 4F_{2(g)} \longrightarrow 2HF_{(g)} + SF_{6(g)}$$

If you knew that the formation temperatures are as follows:

$$H_2S = -21 \text{ kJ/mol}, HF = -273 \text{ kJ/mol}, SF_6 = -1220 \text{ kJ/mol}$$

2. When dissolving one mole of ammonium nitrates in an amount of water and the volume was completed to 1000 ml, the temperature was decreased by 6°C. Calculate the amount of absorbed heat (assume that the solution's density = 1 g / ml and the specific heat of the solution = 4.18 J / g°C)
3. If you knew that the standard change in the heat content for the combustion of octane liquid (C_8H_{18}) is -1367 kJ / mol. Write the expressive chemical equation of the complete combustion of one mole of this liquid in an excess amount of oxygen.

Unit Four Revision Questions

First: Write the scientific term :

1. The amount of absorbed or released heat from forming one mole of a substance from its primary elements in its standard condition. ....
2. The amount of heat needed to raise the body temperature one degree Celsius. ....
3. A chemical equation that includes the change in heat accompanying the reaction. ....
4. The amount of absorbed or released heat when dissolving one mole of the solute in an amount of the solvent to get a saturated solution. ....
5. The heat of reaction is a fixed amount in standard conditions whether the reaction is conducted in one step or a number of steps. ....

Second : Re-write the following statements after correcting the underlined :

1. Heat is considered a measurement for the average kinetic energy of the molecules that form the substance or the system. ....
2. The joule is known as the amount of required heat to raise the temperature of 1 g of water one degree Celsius (from 15°C to 16°C). ....
3. The specific heat measuring unit is the J. ....
4. Chemical energy derives in the molecule from level energy which is the sum of the electron kinetic energy in addition to its potential energy. ....
5. The change in the heat content is the sum of the stored energy in one mole of the substance. ....
6. The system is opened when there is no transportation of either the energy of the substance between the system and the surrounding medium. ....
7. The thermometer is used as an isolated system to measure the absorbed or released heat in the chemical reaction. ....
8. The heat content of the substance is the sum of all internal energies in 1 Kg of this substance. ....

Third : How can you explain ?

1. The dissolving of potassium iodide in water is considered endothermic.

2. Hess's law is considered one of the forms of the first law of dynamic heat.

3. When the dilution process occurs, the amount of solvent increases and produces in increase in the value of (ΔH).

4. The burning of glucose $C_6H_{12}O_6$ inside the bodies of living organisms is considered one of the important combustion reactions.

5. Scientists usually refer to use indirect methods to calculate the reaction heat.

Fourth : Various Questions :

1. A sample was absorbed from an unknown substance with a mass of 155 g of heat of 5700 J so the temperature raised from 25°C to 40°C calculate its specific heat.

2. Calculate the released heat when cooling 350 g of mercury from 77°C to 12°C if you knew that the specific heat of mercury is 0.14 J / g.°C

3. Methane gas CH_4 is considered the main component of natural gas. If you knew that $\Delta H^\circ_c = -965.1$ kJ/mol and $\Delta H^\circ_f = -74.6$ kJ/mol Calculate both the amount of released heat when forming 50 g of methane gas and also when combusting 50 g of it.

4. Calculate the change in the heat content when dissolving 80 g ammonium nitrates in an amount of water to form one liter of the solution knowing that the initial temperature is 20°C became 14°C and answer the following questions:

   A. Is the solubility exothermic or endothermic? Mention the reason.

   ....

   B. Can this heat change be expressive of the molar heat of solubility or not? Knowing that [N = 14 , O = 16 , H = 1]

   ....

5. If you knew that the heat of combustion of ethanol C_2H_5OH is 1367 kg/mol Write the expressive thermochemical equation knowing that the products of the combustion is carbon dioxide gas and water vapor and calculate the produced heat of combusting 100 g of alcohol knowing that [C = 12 , O = 16 , H = 1]

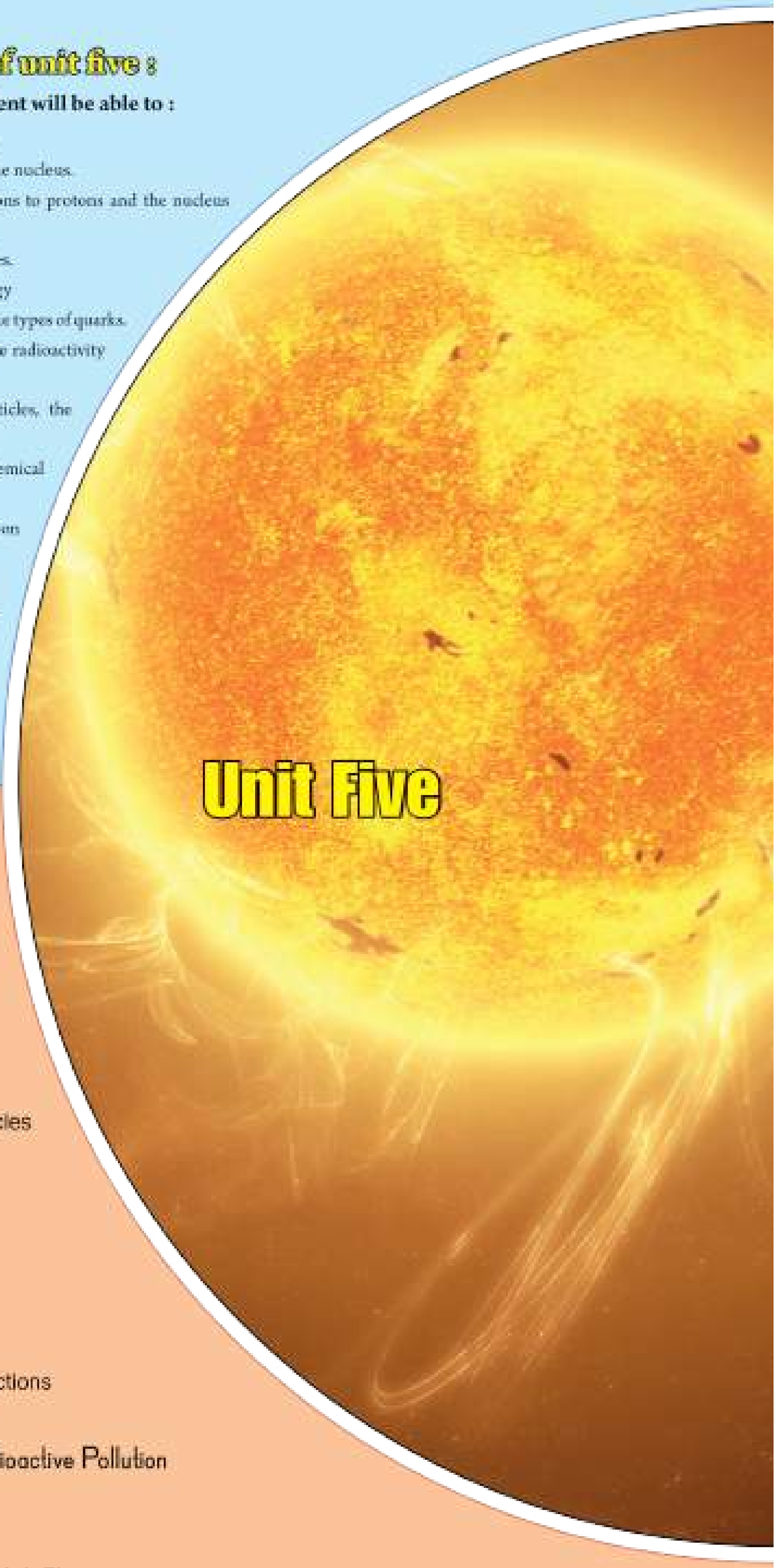
   ....

   ....

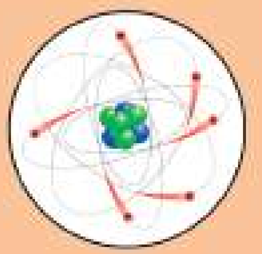
General objectives of unit five :

By the end of this unit, the student will be able to :

- Identify the components of an atom.
- Describe the nuclear force found in the nucleus.
- Connect between the ratio of neutrons to protons and the nucleus stability.
- Define isotopes and mention examples.
- Understand the nuclear binding energy
- Recognize the concept of quark and the types of quarks.
- Mention the historical timeline of the radioactivity phenomenon.
- Distinguish between the alpha particles, the beta particles, and the gamma rays.
- Compare between the nuclear and chemical reactions.
- Compare between the nuclear fission and the nuclear fusion.
- Know the harmful effects of rays.
- Recognize the appropriate usages of rays.



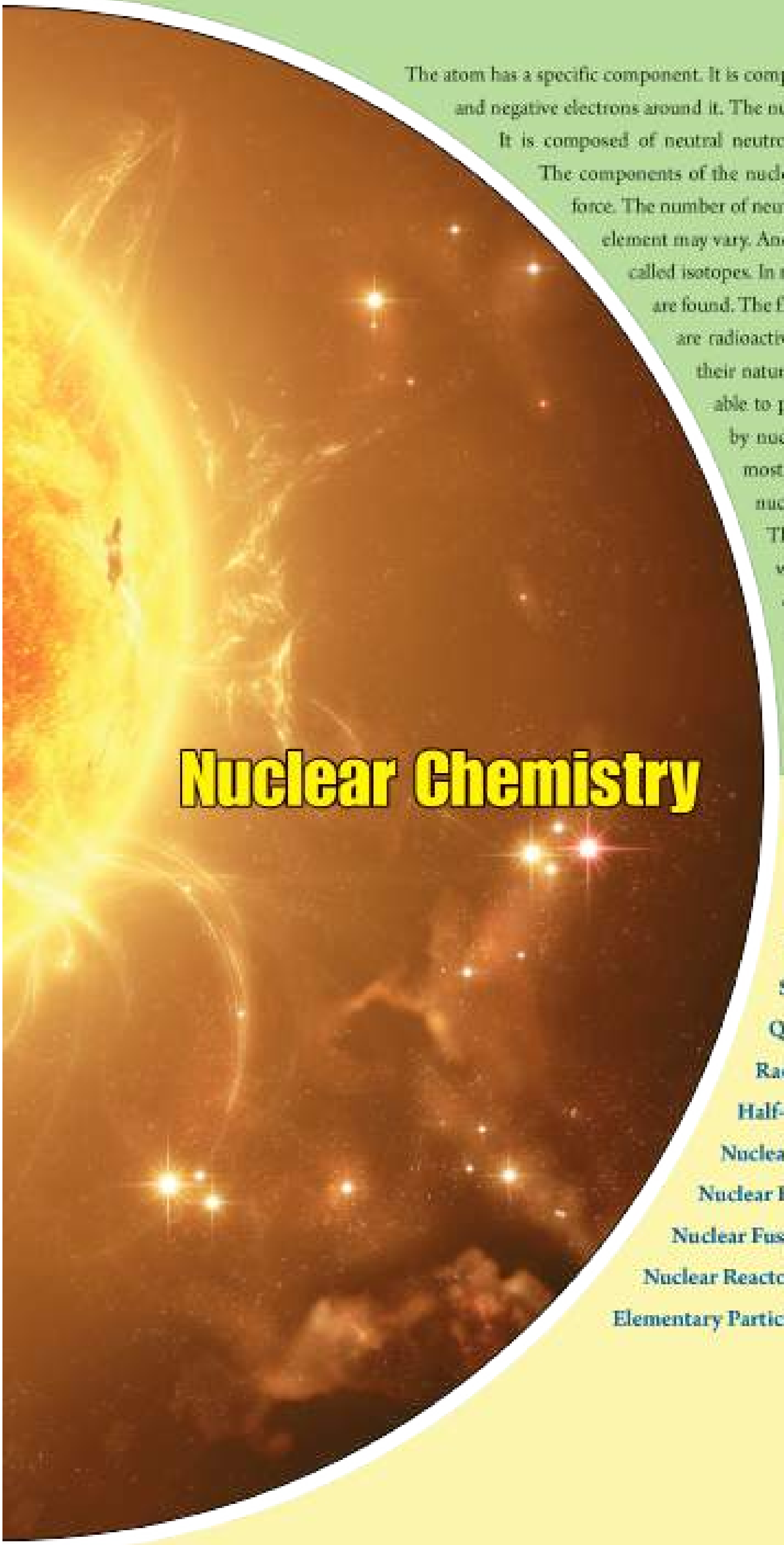
Unit Five Chapters :



(1) Nucleus and Elementary Particles

(2) Radioactivity and Nuclear Reactions

Involved Issues : Radioactive Pollution

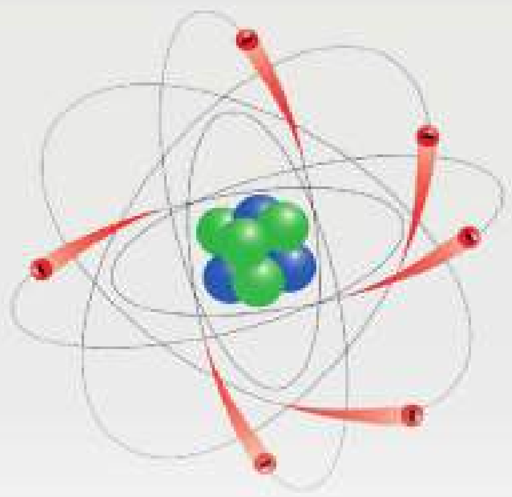


Nuclear Chemistry

The atom has a specific component. It is composed of a positively charged nucleus and negative electrons around it. The nucleus also has a specific component. It is composed of neutral neutrons and positively charged protons. The components of the nucleus are held together by the nuclear force. The number of neutrons in the atoms nuclei of the same element may vary. And therefore, each element has what is called isotopes. In nature, two types of element isotopes are found. The first are stable isotopes and the second are radioactive isotopes that are distinguished by their natural radioactivity. Scientists have been able to prepare artificial radioactive isotopes by nuclear reactions of various types. The most distinct nuclear reactions are the nuclear fissions and the nuclear fusions. This chapter conveys these topics within two lessons. The first lesson deals with the structure of the atom's nucleus while the second lesson deals with radioactivity and nuclear reactions.

Key Terms :

- Isotopes
- Nuclear Force
- Stable Nucleus
- Quark
- Radioactivity
- Half-life
- Nuclear Reaction
- Nuclear Fission
- Nuclear Fusion
- Nuclear Reactor
- Elementary Particles



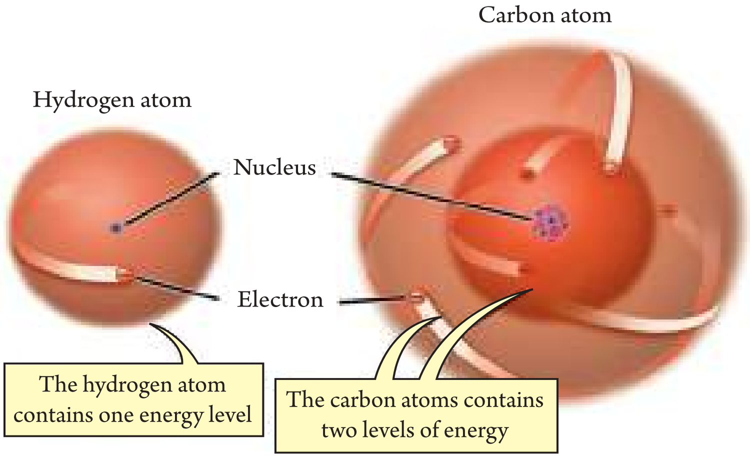
Lesson One : Nucleus and Elementary Particles

Learning Outcomes

By the end of this lesson, you will be able to:

- ✓ Identify the components of an atom and the nuclear amount that classify the nucleus.
- ✓ Find out what isotopes mean.
- ✓ Understand the properties of the nuclear force.
- ✓ Identify the nuclear binding energy and calculate it.
- ✓ Connect between the nuclear stability and the ratio between the number of neutrons to protons in the nucleus.
- ✓ Identify the main and elementary particles in the atom.
- ✓ Know the quark model and use it.

Atom Components



▲ **Figure (1) The atom is composed of a nucleus with electrons revolving around it in the energy levels**

It is known that matter is composed of atoms. These atoms show the physical and chemical properties of the matter. By the end of the nineteenth century, scientists had become sure that **electrons** are of the main components of atoms. These electrons are particles with a very small mass and have a negative charge. And since the atom is electrically neutral, this means that the atom carries a positive charge equal to the negative charge of the electrons. However, the manner of distribution of these charges in the atom was not known during that time.

The scientist, Rutherford (1871 – 1937), constructed a model to describe the atom. He reached this model after many trials. He described the atom as a relatively heavy nucleus in which the atom's mass is concentrated. The nucleus carries the positive charge of the atom and negatively charged electrons rotate around it at a relatively far distance. According to Rutherford-Bohr's Model, the electrons revolve around the nucleus in certain constant orbits called energy levels. Each level is occupied by a certain number of electrons that cannot be increased.

Rutherford's calculations concluded that the nucleus's diameter is ranged between $10^{-6}:10^{-5}$ nm while the atom's diameter is approximately (0.1nm).

In 1919, Rutherford proved that the atom's nucleus contains particles that carry the positive charge called protons. The protons have a mass that is larger than the electron's mass by approximately 1800 times. During the same year, Nevil Sidgwick discovered that the nucleus neutrally charged called neutrons. The mass of a neutron equals the mass of a proton.

Mass Number and Atomic Number

Scientists described the atom's nucleus of any element by using three atomic amounts, which are:

1. Mass number (A) 2. Atomic number (Z) 3. Neutron number (N)

The following schedule shows these amounts:

Term	Symbol	Relation
Mass number	A	Number of protons + number of neutrons
Atomic number	Z	Number of protons=number of electrons
Neutron number	N	N = A - Z

▲ Table (1) Nuclear quantities

It is observed that:

- The protons and neutrons inside the nucleus are known as nucleons.
- The number of protons (Z) in the nucleus is equal to the number of electrons around the nucleus in the case of the neutral atom.

Nucleus's Symbol

If we assume an element with a chemical symbol (X), the nucleus of this element atom can be described by the following method:

$$^{A}_{Z}X$$

A (mass number = proton number + neutron number)

Z (atomic number = proton number)

and sometimes the symbol is written as follows: $^{A}_{Z}X_{N}$

Example:

Write the chemical symbol for the nucleus of an aluminum atom, if you knew it contained 13 protons, in addition to 14 neutrons.

Solution:

The aluminum element symbol is Al , and the nucleus symbol for the aluminum atom is $^{27}_{13}Al$

Isotopes

Isotopes: are atoms of the same element that have the same atomic number (Z), i.e. the nuclei of the atoms have the same number of protons and differ in the number of neutrons.

This means that the atoms of the isotopes are similar in the number of electrons and their distribution around the nucleus, and therefore, are similar in their chemical reactions.

The examples of isotopes are abundant as most of the elements in the periodical table have isotopes. Even the simplest element found in nature, which is hydrogen, has three isotopes $^{1}_{1}H$, $^{2}_{1}H$, $^{3}_{1}H$ The nucleus of the isotope $^{1}_{1}H$ is composed of a proton. The nucleus of the isotope atom $^{2}_{1}H$ is called deuteron. It contains proton and neutron while the tritium nucleus considered as a proton and neutron.

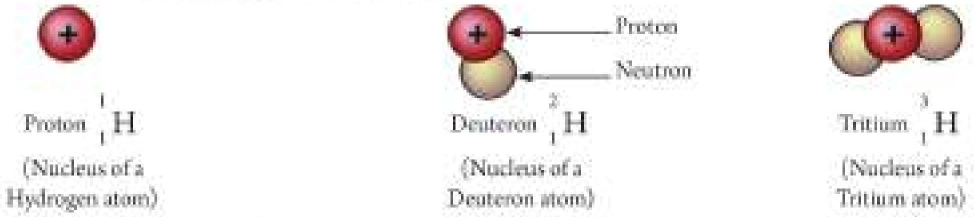


Figure (3) The nuclei of atoms of hydrogen isotopes

Example:

Atomic masses of elements can be identified in terms of the relatively atomic masses of their isotopes and the ratio of the presence of each.

Example: calculate the atomic mass of copper knowing that it is found in the nature in the form of two isotopes; Cu^{63} 69.09% and Cu^{65} 30.91%)

solution:

contribution of Cu^{63} in the atomic mass = $62.9298 \times \frac{69.09}{100} = 43.4782$ amu

contribution of Cu^{65} in the atomic mass = $9278 \times \frac{30.91}{100} = 20.069$ amu

the atomic mass of copper = 43.4782 + 20.069 = 63.55 amu

Enrichment Information

In nuclear chemistry, other nuclear terminology is used in addition to the isotopes, which are:

- Isobars: they are the nuclei of atoms of different elements that have the same number of mass (A), but they differ in the atomic number (Z). An example of this is ${}^{17}_{9}F$, ${}^{17}_{8}O$
- Isotones: they are the nuclei of atoms of different elements that have the same number of neutrons, but they differ in the mass number like: ${}^{17}_{9}F_8$, ${}^{16}_{8}O_8$

Mass and Energy Units

It is known that the unit of measuring mass in the International System of Units is the kilogram. However, since the atom masses of the element isotopes are very small, It is estimated by the atomic mass unit (a.m.u.) and abbreviated by the symbol (u) and it is equavelant to 1.66 × 10-27 Kg.

When a mass of (1u) completely transforms into energy, as occurs in some nuclear reactions, then the amount of product energy (E) can be calculated according to Einstein's equation from the relation:

$$E = m c^2$$

As (m): the mass transformed into energy estimated in kilograms

(c): the speed of light in air. It equals (3×10^8 m/s)

$\therefore E = (1.66 \times 10^{-27}) \times (3 \times 10^8)^2$

$E = 14.94 \times 10\text{-}11 \text{ Joule} = \dfrac{14.94 \times 10^{-11}}{1.605 \times 10^{-11}} = 931 \text{ MeV}$

From the previous, it is shown that there is an equilibrium between mass and energy. i.e.

$$\therefore 1 \text{ amu} \simeq 931 \text{ MeV}$$

Did you know ?

Another unit is used for measuring the energy besides the joule, called electronvolt and is denoted by the symbol (eV) as:

$$1 \text{ eV} = 1.602 \times 10^{-19} \text{ J}$$

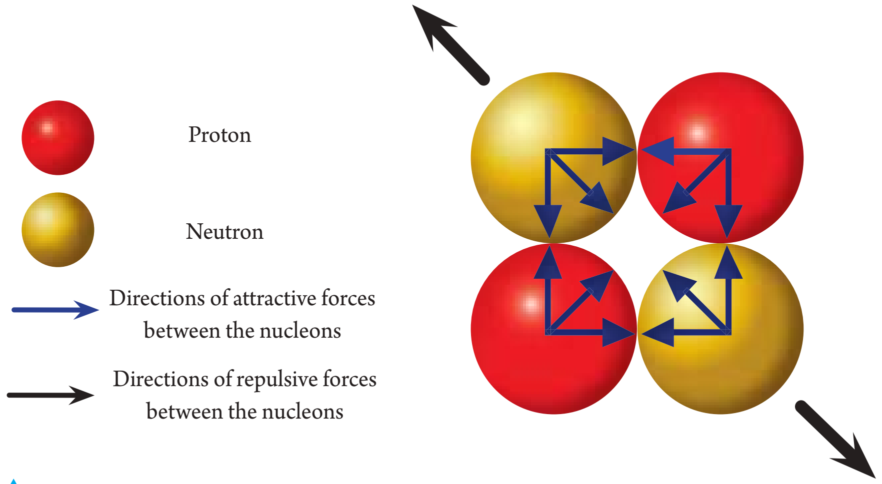
There is a larger unit called one million electronvolt, and is denoted by the symbol (MeV) as:

$$1 \text{ MeV} = 1.602 \times 10^{-13} \text{ J}$$

Nuclear Forces

We have mentioned at the beginning of this lesson that the nucleus is composed positively charged protons and neutrons that do not have a charge. But what makes the atom nucleus bind? What leads to the stability of nucleons inside the nucleus?

It is known that protons in the nucleus repulsive to one another due to the electric forces. As such, it is impossible for the nucleus to become stable if the only force between the protons is the coulomb electric force. Undoubtedly there is an attractive force between the nucleons inside the nucleus, like the attractive force between any two bodies. However, this amount of attractive force is very small and does not equal with the electric repulsive force between the nucleons.



▲ Figure (5) If the attractive force between the nucleons is very small, then there must be a force working on pushing the nucleons towards each other

It is clear that the accumulation of the nucleons inside the nucleus cannot be stable except in the presence of other forces working on the combining of these nucleons. This force is called the nuclear force. The nuclear force has the following properties:

- Short – range force.
- Does not depend on the essence of the nucleons, as it is one of the following pairs: (proton – proton , proton – neutron , neutron – neutron).
- It is a great force.

Nuclear Binding Energy

It have proven that the nucleus mass , when it is stable , is less than the sum of the masses of nucleons forming it. This lose im mass is a characteristic property for each nucleus and is converted into an energy used to bend the components of the nucleus to be combined with each other inside the infinite small nuclear space and called "the nuclear bending energy".

By using Einstein's law to transform mass into energy, then:

mass defect= theoritical mass- actual mass.

Nuclear binding energy (MeV) BE= [mass defect $\times$ 931

As m_n , m_p Neut ron mass and proton mass successively, Mx the actual nucleus mass.

The value in which each nucleon contributed in the binding energy of the nucleus is called the binding force for each nucleon, and it equals: ($\frac{BE}{A}$)

Example:

If the actual mass of the nucleus of helium atom is ${}_{2}^{4}He = 4.00150$ u

Calculate the nuclear binding (MeV) for ${}_{2}^{4}He$ nucleus , then calculate the binding energy per nucleon , knowing :

proton mass = 1.007284

neutron mass = 1.008664

Solution:

${}_{2}^{4}He$ nucleus consists of 2 protons and 2 neutrons , the B.E. calculated as follows :

$$BE = [(2 \times 1.00728 + 2 \times 1.00866) - 4.00150] \times 931 \text{ MeV} = 28.28 \text{ MeV}$$

$$\frac{BE}{A} = \frac{28.28}{4} = 7.07 \text{ MeV}$$

Nucleus Stability and the Neutron / Proton Ratio

The stable element is known as: the element in which it atom's nucleus remains stable throughout time. It has no radioactivity. As for the unstable element, its nucleus disassembles with time through radioactivity. So if we draw a diagram relation between the number of neutrons (N) and the number of protons (Z) for all the stable nuclei of the elements and for those found in the periodic table, we get a curve as in the below figure:

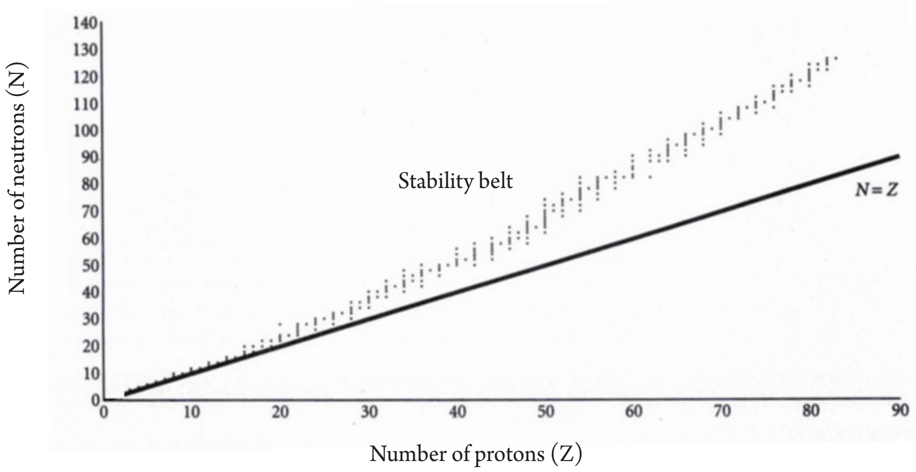


Figure (6) Stability line, each point on this diagram represents a stable nucleus

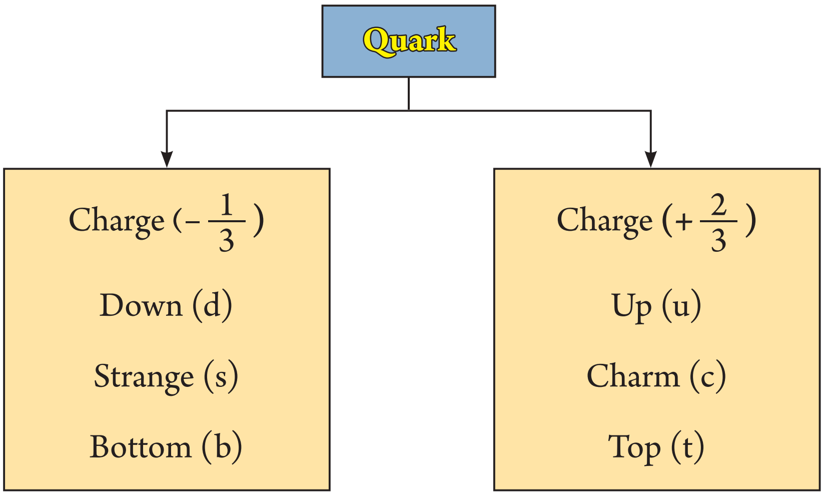
By studying this diagram, we find that:

- The light and stable nuclei of the elements have a number of neutrons equaling the number of protons and the ratio is 1:1. This ratio gradually increases whenever we move to the heavier elements in the periodic table until it reaches a ratio of 1 : 1.53 in the case of the nucleus of lead $^{208}_{82}Pb$
- The nucleus of the element that is located on the left side of the stability belt has mostly an unstable nucleus. The number of neutrons is larger than the stability level. This nucleus acquires its stability by the transformation of one of the extra neutrons into a proton and the emission of a negative electron called the beta particle, and is denoted by the symbol $\overline{\beta}$
- The nucleus of the element that is located on the right side of the stability curve has a number of protons is larger than the stability level. This nucleus acquires its stability by the transformation of one of the extra protons into a neutron and the emission of a positive electron called the positron, and is denoted by the symbol $^{+}\beta$ As such, the neutron-proton ratio in the nucleus is amended to get close to the stability curve.
- The nucleus of an element that has a large atomic number and its location is above the stability curve can acquire its stability by emission of 2 protons and 2 neutrons in a particle form called an alpha particle and is denoted by the symbol α

Concept of Quark

In 1964, the American physicist, Murray Gell-Mann, proved that the protons are an accumulation of primary particles called quarks and their number is 6 types, each one is characterised by a number which is called Q which express its relative charge to the electron's charge and its value are $+\frac{2}{3}$ e or $-\frac{1}{3}$ e

The following schedule shows the types of quarks: :



Composition of proton:

The proton consists the combination of two upper quarks (u) with one lower quark (d).

the electrical positive charge of the proton Qp is interpreted as it is the sum of the three quark charges forming it.

$$Q_p = \underset{(u)}{\frac{2}{3}} + \underset{(u)}{\frac{2}{3}} - \underset{(d)}{\frac{1}{3}} = +1$$

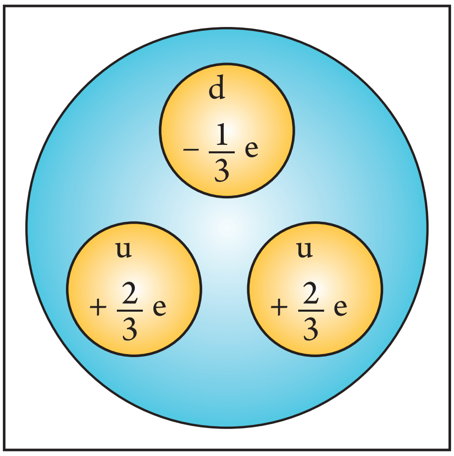


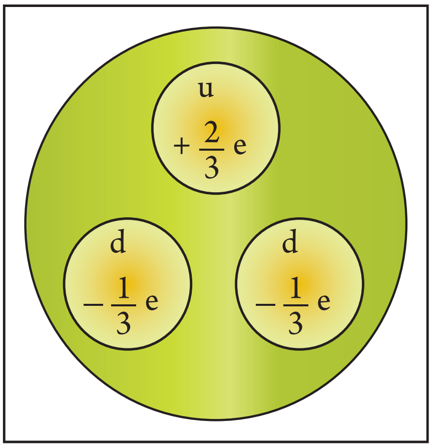
Figure (6) Composition of proton:

Composition of Neutron:

The Neutron consists the combination of one upper quark (u) with two lower quarks (d).

the electrical neuteral charge of the neutron Q_N is interpreted as it is the sum of the three quark charges forming it.

$$Q_n = \underset{(u)}{\frac{2}{3}} + \underset{(d)}{\left(-\frac{1}{3}\right)} + \underset{(d)}{\left(-\frac{1}{3}\right)} = 0$$



▲ Figure 7: Composition of neutron

Lesson Two : Radioactivity and Nuclear Reactions

Learning Outcomes

By the end of this lesson, you will be able to:

- ✓ Understand the phenomenon of radioactivity.
- ✓ Compare between alpha, beta, and gamma rays.
- ✓ Understand what is meant by half-life of the radiant element.
- ✓ Classify the nuclear reactions.
- ✓ Compare between the reactions of nuclear fission and nuclear fusion.
- ✓ Understand the scientific base for the function of a nuclear reactor.
- ✓ Specify some of the negative side effects of radiation.
- ✓ Number some of the peaceful usages of radiation.

One of the important discoveries that lead to the great advancement in our information about the atom and its composition was the detection of the radioactivity phenomenon The scientist, Henri Becquerel, made this discovery in of 1896. The first to give this phenomenon this name was Marie Curie in 1898.

When the radioactivity phenomenon was revealed, researchers gave their attention to know the nature of these shooting rays from the radiant substances and compare their properties. Two methods were followed in doing this, which are:

- Testing the capability of rays to permeate through substances.
- Testing the deviation of rays by the effect of both the magnetic field and the electric field.

The experiments inferred that there are three different rays that are radiated from the natural radioactive substances, which are:

- Alpha rays α: particles is formed from two protons and two neutrons, i.e. each particle is the nucleus of the helium atom. So, the alpha particle in nuclear reactions is denoted by the symbol $^{4}_{2}He$

- Beta rays: are particles that carry the characteristics of electrons ($^{0}_{-1}e$) in terms of mass and speed. Beta rays emitt from the nuclei of atoms of radiant elements or in the nuclear reactions. The mass of the beta particle is ignored in proportion to the atomic unit masses. Its charge equals the negative charge unit, and is denoted by the symbol (β^-).
- Gamma rays: are electromagnetic waves with a very short wavelength. Its speed equals the speed of light. It is the shortest electromagnetic wave in its wavelength after the universal ray, and therefore it has a high frequency and a large photonic energy. Since gamma rays are electromagnetic rays, it does not carry a charge and has no mass. Therefore, its emergence from the nucleus of an atom of a radiant element does not lead to any change in the atomic number or the mass number of this nucleus. Gamma rays emitt from the nuclei of elements when these nuclei are unstable (its energy is more than in its stable state).

The following table shows a comparison between the properties of the three types of rays that are radiated from a radiant substance.

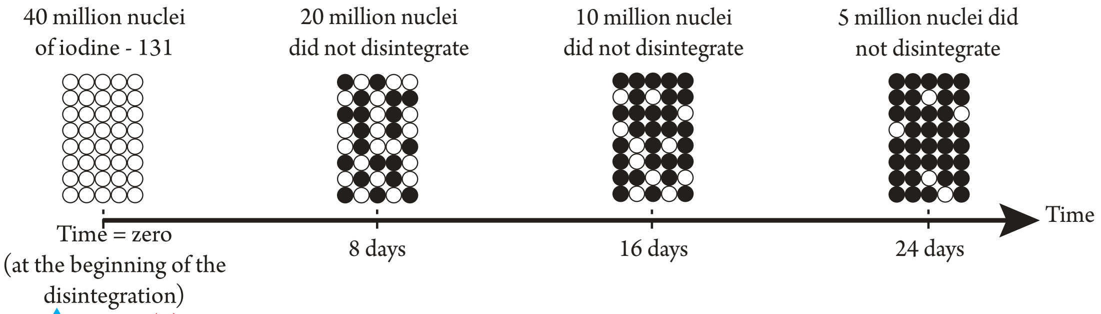
Radiation	Symbol	Nature of radiation	Estimated mass	The ability to ionize the medium passing through	Ability to permeate	Deviation in the magnetic or electric field
Alpha	α $^{4}_{2}He$	Helium nucleus 2 protons 2 neutrons	Four times of proton mass	Has strong capability	Weak - cannot pass through thin paper	Small deviation
Beta	β $^{0}_{-1}e$	Electron	$\frac{1}{1800}$ of the protons mass	Less than Alpha's capability	Average A 5 mm aluminium slice prevents its passing	Large deviation
Gamma	γ	Electromagnetic waves	-----	The least powered	Quite high More premeable passing throught lead slice of a few centimeters thick	Does not deviate

Table (3) Comparison between the properties of the three types of rays

Half - life

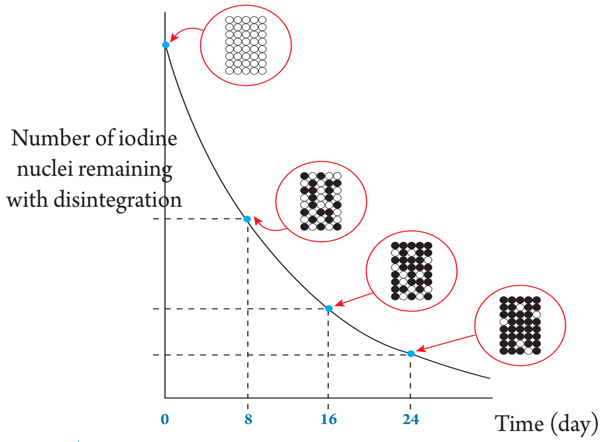
When the alpha particles or beta particles or gamma rays emitte from the nucleus of the atom of the radiant element, it is said: this nucleus has occurred to it a radioactive decay. the activity of the radioactive material decreases over time and the time needed to decay the number of the neuculs atoms of the radioactive element into a half is called half - life t1/2.

For example, if we take a sample of the radioactive iodine sample (iodine –131), only one nucleus disintegrates every second from between 1,000,000 iodine nuclei found at that moment. The following figure represents the disintegration of iodine –131.



▲ **Figure (9) Amount of time in which the number of iodine nuclei decrease by radiation to half the original number is called half-life. In this figure ○ Represents one million iodine nuclei that have not disintegrated yet, and ● Represents one million iodine nuclei that have disintegrated.**

The disintegration of iodine -131 can be represented by drawing a graph relation as in figure (10).



▲ **Figure (10) Radioactive decay curve of iodine -131. Half-life has 8 days**

Example:

Calculate the half-life of a radioactive element knowing theat a sample of it has a mass of 12 g and remain 1.5g of it after 45 days.

solution:

$$12\text{ g} \xrightarrow[(1)]{t_{\frac{1}{2}}} 6\text{ g} \xrightarrow[(2)]{t_{\frac{1}{2}}} 3\text{ g} \xrightarrow[(3)]{t_{\frac{1}{2}}} 1.5\text{ g}$$

$$\because D = 3 \qquad \therefore\ t_{\frac{1}{2}} = \frac{t}{D} = \frac{45}{3} = 15 \text{ days}$$

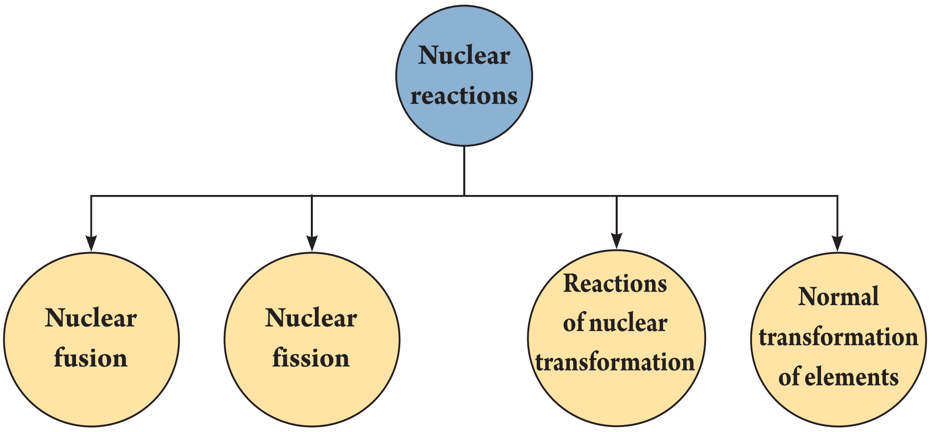
What does it mean that the half-life of radioactive iodine-131equals 8 days?

This means that the time in which the number of nuclei of the radioactive iodine element decreases to half its original number by radioactive decay equals eight days.

Nuclear Reactions

Nuclear reactions are reactions that include the change in the composition of the nuclei of the reactant elements and the formation of new nuclei when the nuclei of the reacting atoms interact. Nuclear reactions are different than chemical reactions. As a chemical reaction occurs between the atoms of the elements by combining between the existent electrons in the outer energy levels for the atoms of the reactant elements, and no change occurs to the nuclei of these atoms.

Nuclear reactions can be classified to the following types:



Natural Transmutation

This transformation occurs to the nuclei of atoms of elements that are located above the stability curve or below it. As these nuclei have a ratio $(\frac{N}{Z})$ that differ from this ratio for the stable nuclei that are located on the curve. The product of this transformation is that the unstable nucleus spontaneously changes to transform into another nucleus by the emission of alpha rays and beta rays.

For example: the uranium-238 nucleus disintegrates into a thorium-234 nucleus by the emission of an alpha particle. This reaction is described by the following nuclear equation:

$$^{238}_{92}U \longrightarrow \, ^{234}_{90}Th + \, ^{4}_{2}He$$

It is observable from this equation that uranium-92 is transformed into another element which is thorium-90. It is also noticeable that the number of mass (A) of the original nucleus equals the sum of the mass numbers for the alpha particle and the produced nucleus. The atomic number (Z) is also equal in the two sides of the nuclear equation.

The nucleus of the radioactive carbon atom $^{14}_{6}C$ transforms into the nucleus of a nitrogen atom $^{14}_{7}N$ By the emission of a beta particle. Remember that the beta particle is an electron emitting from a nucleus. This reaction is expressed by the following nuclear equation:

$$^{14}_{6}C \longrightarrow {}^{14}_{7}N + {}^{0}_{-1}e$$

Notice that when emitting the beta particle, a neutron in the carbon nucleus had transformed into a proton, which leads to the increase in atomic number by the one, and the mass number (number of nucleons) remains the same. Notice also that the beta particle is denoted by the symbol $^{0}_{-1}e$ as the number (-1) represents an electron charge. But the zero, means the mass is neglected in comparison to the mass of the proton or neutron. In this equation, we observe the equilibrium of both the mass number (A) and the atomic number (Z).

Nuclear Transformation:

If we want two nuclei to react, we accelerate one of them in order to acquire appropriate energy movement so that it can come closer to the other nucleus. The nucleus that is accelerated is called the bomb, while the other nucleus is called the target. Examples of bombs are the proton $^{1}_{1}H$, the deuteron $^{2}_{1}H$, and the alpha particle $^{3}_{1}H$

These bombs can be accelerated by using devices called nuclear accelerators like the Van de Graaf accelerator and the Cyclotron accelerator. The first to conduct an artificial nuclear reaction was Rutherford in 1919. He discovered that when alpha particles pass through nitrogen gas, the alpha particles merge with the nucleus of the nitrogen atom to form the nucleus of a fluorine atom $^{18}_{9}F$ and is called the nucleus compound. This nucleus is unstable and with a high energy. It rids of the excess energy to return to the stable condition, and a proton $^{1}_{1}H$ Accelerates and the nucleus of the nitrogen atom transforms into the nucleus of an oxygen atom.

From here, it is possible to look at this nuclear reaction as requiring two steps:

- First step : $[^{18}_{9}F^{*}] \longrightarrow {}^{14}_{7}N + {}^{4}_{2}He$
- Second step : $[^{18}_{9}F^{*}] \longrightarrow {}^{17}_{8}O + {}^{1}_{1}H$

It is clear that in an artificial nuclear reaction, the reacting elements transform into other different elements. In Rutherford's experiment, nitrogen transformed into oxygen.

The following are other examples of artificial nuclear reactions that lead to the transformation of elements into other elements:

$$^{27}_{13}Al + {}^{1}_{1}H \longrightarrow [^{28}_{14}Si^{*}] \longrightarrow {}^{24}_{12}Mg + {}^{4}_{2}He$$

$$^{26}_{12}Mg + {}^{2}_{1}H \longrightarrow [^{28}_{13}Al^{*}] \longrightarrow {}^{24}_{11}Na + {}^{4}_{2}He$$

$$^{6}_{3}Li + {}^{1}_{0}n \longrightarrow {}^{3}_{1}H + {}^{4}_{2}He$$

It is important that we pay attention, when balancing the nuclear equations, to abide by the two laws of 'charge preservation' and 'matter and energy' preservation.

The law of charge preservation requires the sum of the atomic numbers at the left hand side of the equation to be equal to the sum of the atomic numbers at the right hand side of the equation. The law of matter and energy preservation requires us to preserve the mass number. In other words, the sum of the mass number at the left hand side of the equation is equal to the sum of the mass number at the right hand side of the equation.

Nuclear Fission

In 1939, scientists discovered a type of nuclear reactions called nuclear fission. Nuclear fission is the division of a heavy nucleus into two nucleuses that are close in mass due to a certain nuclear reaction. When the nucleus of a uranium-235 atom is bombarding by a a neutron, the neutron does not need a high acceleration to be able to enter the nucleus as it does not find repulsion. It is considered an neutral bomb. The slow neutron enters into the nucleus of uranium-235, which transforms into uranium -236 isotope. It is an unstable uranium that does not last longer than 10^{-12} seconds. The nucleus $^{236}_{92}U$ then divides into the two nucleuses (X) and (Y), which are called the fragments of nuclear fission. There are various potential possibilities for these fragments as there are 90 new and variant nuclei that could be produced form this fission. It most likely produces between two or three neutrons in the process. This reaction can be represented by the following equation:

$$^{235}_{92}U + ^{1}_{0}n \longrightarrow [^{236}_{92}U^{*}] \longrightarrow X + Y + 2 \text{ or } 3\,^{1}_{0}n$$

One of the well-known products of nuclear fission is barium and krypton according to the equation:

$$^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{141}_{56}Ba + ^{92}_{36}Kr + 3\,^{1}_{0}n$$

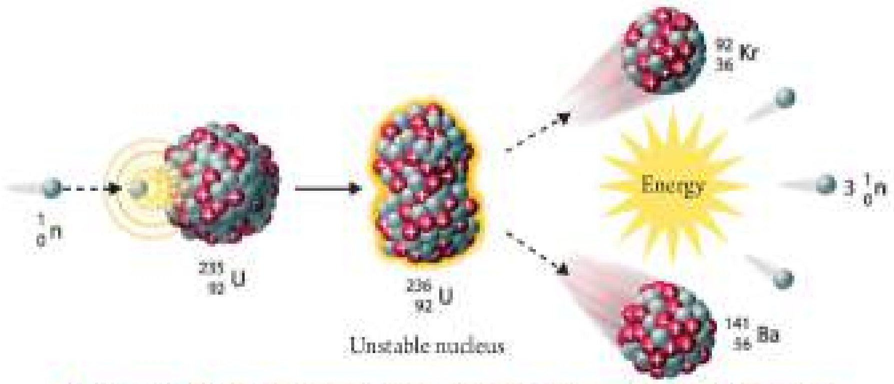


Figure (11) Nuclear fission of uranium -235 when bombarded with a neutron

Nuclear Fusion

The division of a heavy nucleus into two average nuclei is called the nuclear fission. The opposite of this reaction is the fusion of two light nuclei to form a heavier nucleus is another nuclear reaction called the nuclear fusion. For example, if two deuterons are integrated together to form a helium nucleus, then the nucleus mass of the helium is less than the sum of both masses of the two deuterons. This difference in mass transforms into energy estimated to be 24 million electronvolt that is freed with the fusion of these two deuterons. This nuclear fusion can be represented by the following nuclear equation:

$$^{2}_{1}H + ^{2}_{1}H \longrightarrow ^{3}_{2}He + ^{1}_{0}n + 24\ MeV$$

For the occurrence of a nuclear fusion, a high temperature that reaches to rank 10^7 K must be present. Due to this high temperature, the nuclear fusion is difficult to achieve in laboratories. Although this reaction occurs inside the Sun (as occurs inside most stars) as temperatures reach up to millions of degrees Celsius. The nuclear fusion is the source of the destructible energy of the hydrogen bomb.

Nuclear Reactor

We have seen in the nuclear fission reaction that a group of neutrons are produced from the reaction, in addition to the fission fragments. Each one of these neutrons (if its speed is appropriate) can split a new nucleus from the nuclei $^{235}_{92}U$ These new fissions produce other new neutrons that can perform the same previous reaction, and so it splits other nuclei of the nuclei $^{235}_{92}U$ and so forth. This reaction is called a serial reaction. Figure (12) shows how to duplicate the number of nuclei that split if the reaction continues in this manner.

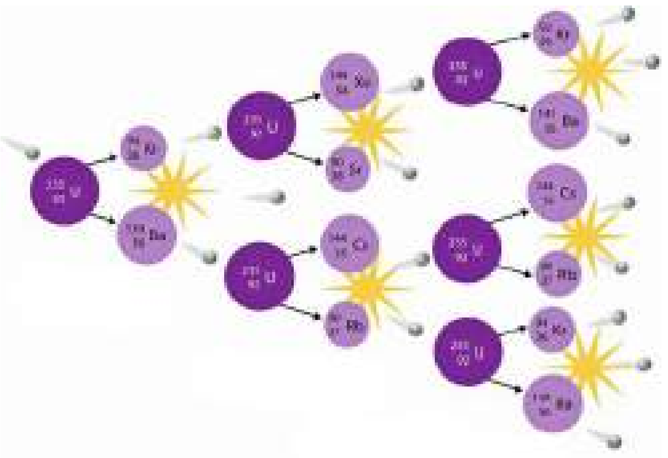


Figure (12) The serial reaction starts by the nucleus of the uranium atom bombarding a neutron

This serial reaction generates huge thermal energy that increases with the continuation of the reaction if it was possible to use the largest number of produced neutrons. This is the function concept of the nuclear fission bomb.

Definite volume is an amount of uranium -235 in which one neutron – in average – from each reaction starts a new reaction. In this way, the reaction continuously remains in its same slow initial rate. If the amount of uranium used is much larger than the difinite volume, then the reaction will continue with an accelerated rate that will lead to an explosion. (this may be needed in making a nuclear bomb. If we wanted to control a serial reaction so that it produces at the end energy and does not cause an explosion, in this case, then the number of neutrons produced from the serial reaction must be controlled. This control is performed in the nuclear reactor by using cadmium control rods that are absorbent to neutrons. When these rods are placed inside the reactor, the serial nuclear reaction begins to slow down, and its rate can be controlled in a good manner by controlling the location and number of the cadmium rods. The nuclear reactor is considered as a source of heat energy. The produced heat energy is used to produce electrical energy by using steam turbine.

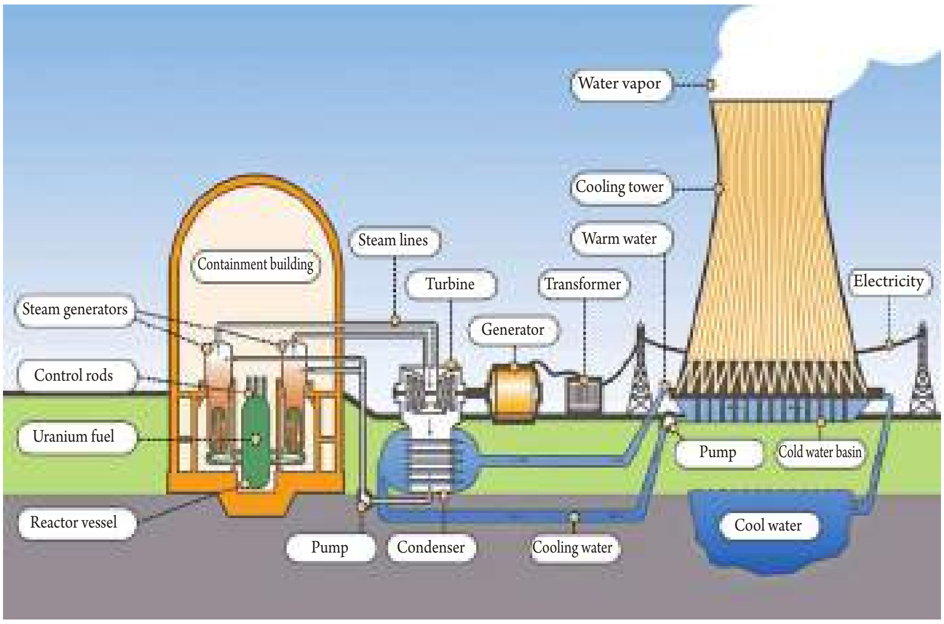


Figure (13) Diagram of a nuclear reactor for producing energy

Comparison between chemical reactions and nuclear reactions :

Chemical reactions	Nuclear reactions
Occur between the electrons of the outermost shells of the atom	Occur between the nuclei of the atoms
There is no transformation of an element to another	Almost there is transformation of an element to another or its isotope
The products are the same if we used different isotopes of the same element	Isotopes of the same element gave different products
Produce small amount of energy	Produce large amount of energy

Table (4) Comparisson between chemical and nuclear reactions

In the medical Field

Gamma rays are emitted from the isotope of cobolt-60 or cesium-137. They are used in destroying carcinogenic cells by directing the gamma rays to the center of the tumor. Radioactive radium-226 is also used in the form of needles that are implanted in the carcinogenic tumor in order to destroy its cells.

In the Industrial Field

Gamma rays are used in the automation of some production lines. An example of this is the automation process in the pouring of molten steel. A source of gamma rays, like cobolt-60 or sicium-137 is placed at one of the sides of the pouring machine and a radioactive reagent that receives gamma rays is placed on the other side. When the iron mass reaches certain dimensions, the reagent cannot receive the gamma rays, and thus, the pouring process stops.

In the Agricultural Field

The seeds are exposed to different dosages of gamma rays to create mutations in their embryos and to select the finest of them to produce plants of greater productivity and resistance to disease. Gamma rays are also used to pasteurize plant and animal products to preserve them from spoilage and increase their storage time. The gamma rays are also used to sterilize male insects to limit the spread of diseases.

In the Scientific Research Field

Research nuclear reactors are used in preparing many radioactive isotopes that are used in various scientific researches. For example, it is possible to know what occurs in plants by placing radioactive substances in the main substances that plants use. The radiations emitted from these substances are traced to know their cycle in the plant, like entering water that has radioactive oxygen and following its track.

Harmful Effects of Radiation

In general, there are two types of radiation:

- Ionized radiation: it causes changes in the composition of tissues that are exposed to it. It includes, for example, alpha rays, beta rays, gamma rays, and X-rays. When these rays collide with the atoms of any substance, it ionizes them. This is why they are called ionized rays.

- Non-ionized radiation: it does not cause changes in the composition of tissues that are exposed to it. Examples of this radiation include radio waves from cellular phones, microwaves, light, infrared rays, ultraviolet rays, and laser rays.

First: Harmful Ionized Radiation

During the falling of ionized radiation on the cell, it leads to the ionization of water molecules that represents the larger part of any living cells. This leads to the ruining of the cell, the breakage of the chromosomes, and to some genetic deformations. On the long-run, effects occur to the cell that lead to:

- Death of the cell
- Preventing or delaying cell mitosis or increasing the rate of its division, which leads to carcinogenic tumors.
- Occurrence of permanent changes in the cell that is genetically transported to the next generations. The result is the birth of new infants that are different than the parents.

Second: Harmful Non-Ionized Radiation

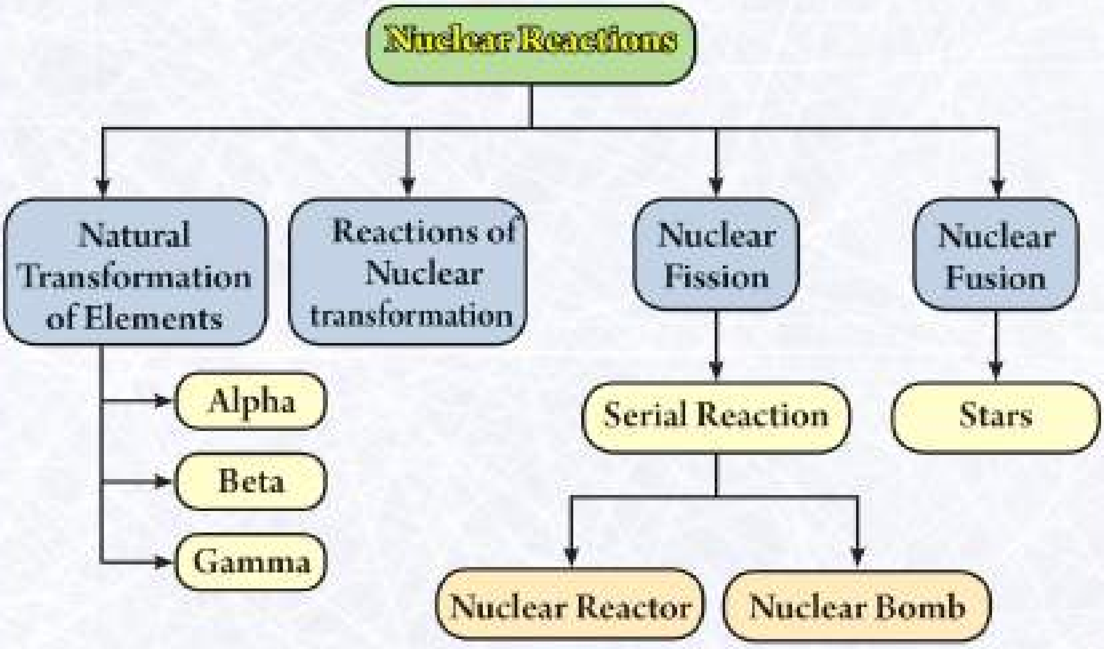
For example, the radiations emitted from the cellular towers may cause physiological changes in the nervous system. The result is that people living close to the areas in which towers are found suffer from headaches, dizziness, and fainting symptoms. Scientists have agreed that the distance between cellular towers and households must be at least 6 meters. This is considered a safe distance.

As for the cellular phones, its danger lays in the radio waves emitted from it as the rays of the magnetic field and the electric field effect these cells. They also cause an increase in temperature of cells due to the absorption of energy by the cells. Some studies have noted that the use of laptops by placing them on the knees effects fertility.

Basic Terminology in Unit Five

- **Isotopes:** are atoms of the same element that have the same atomic number (Z), i.e. the nuclei of the atoms share the same number of protons and differ in the number of neutrons. **Page 92**.
- **Nuclear force:** works on the flowage of nucleons and making them come close together inside the nucleus. **Page 94**.
- **the proton is composed of binding 2 upper quarks (u)with 1 lower quark (d).**
- **the neutron is composed of binding 1 upper quark (d) with 2 lower quarks (u).**
- **Half-life:** amount of time in which the number of radiant nuclei decrease by half their original number by radioactive degeneration. **Page 101**.
- **Nuclear fission:** the division of a heavy nucleus into two nucleuses that is close in mass due to a certain nuclear reaction. **Page 104**.
- **Nuclear fusion:** a nuclear reaction in which two light nucleuses are fused to form a heavier nucleus. **Page 105**.

Organizational Chart of Unit Five



Unit Five
Nuclear Chemistry

Lesson One : Nucleus and Primary Particles

Application Activity : Nuclear Isotopes

Purpose of the Activity

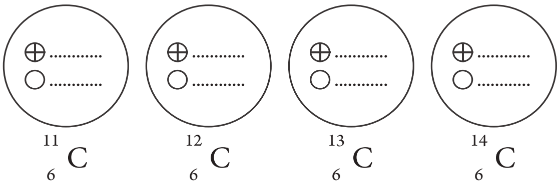
- ☑ Understand what is meant by nuclear isotopes.
- ☑ Compare between the isotopes of nuclei of atoms of the same element.

Acquired Skills

- ☑ Comparing – concluding.

Procedures :

- ✪ Given that: carbon has four isotopes, which are : ${}^{11}_{6}C$, ${}^{12}_{6}C$, ${}^{13}_{6}C$, ${}^{14}_{6}C$
- ✪ Required: if the proton is represented by the figure ⊕ and the neutron by the figure ◯ Show the number of protons and the number of neutrons in the nucleus of each isotope.



Analyzing the results :

- ✪ What are the most widespread isotopes in nature? ....
- ✪ Which of these nuclei is more stable? ....
- ✪ Do the atoms of isotopes have the same chemical properties? Explain your answer.

  ....

- ✪ Complete the following table:

Atom symbol	Mass number	Atomic number	Neutron's number	Neucleon's number
${}^{11}_{6}C$	....	....	....	....
${}^{12}_{6}C$	....	....	....	....
${}^{13}_{6}C$	....	....	....	....
${}^{14}_{6}C$	....	....	....	....

Conclusion :

- ✪ Isotopes are ....

Unit 5

Activities and Assessment Questions

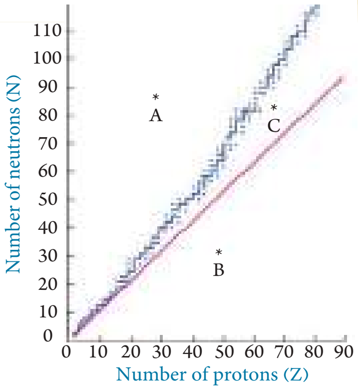
Application Activity : Study the stability of Nuclei

Purpose of the Activity

☑ Correlating between the ratio of the number of neutrons to the number of protons in the nucleus and nuclear stability.

Acquired Skills

☑ Explaining data – applying – concluding.



Procedure :

- Given that: the following graph shows the relationship between the number of neutrons and the number of protons of the stable nuclei of the atoms of the elements found in the periodical table.
- Study this figure and then answer the following questions:

A. What does the dotted line represent in the drawing?

....

B. A , B and C represent the position of three nuclei of atoms of elements outside the stability zone. Which of these nuclei acquires stability by emitting β particle? Explain your answer.

....

C. The following table includes some nuclei that are known for there stability. Complete the data of the table:

Nucleus	Neutron's number	Proton's number	Ratio (N/Z)
$^{208}_{82}Pb$	....	....	....
$^{56}_{26}Fe$	....	....	....
$^{40}_{20}Ca$	....	....	....
$^{23}_{11}Na$	....	....	....

- How can you correlate between the ratio (N/Z) of these nuclei and nuclear stability?

....

Application Activity : Quarks

Purpose of the Activity

☑ Calculate the electric charge for some nuclear particles.

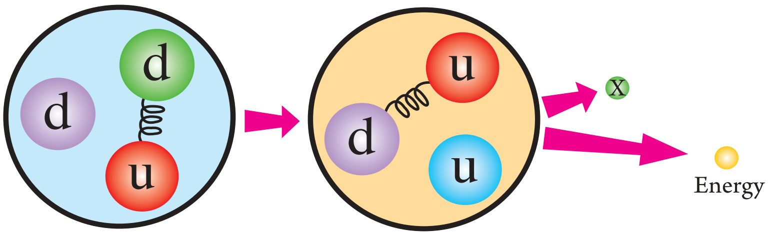
Acquired Skills

☑ Understanding terms – comparing data – concluding .

✪ Given that: the following table shows the amounts of Q for each of the quarks s , d and u relative to the electron.

Quark	Q
u	$+\frac{2}{3}e$
d	$-\frac{1}{3}e$
s	$-\frac{1}{3}e$

Study the following figure then answer the questions :



✪ Calculate the electric charge for the proton and the neutron.

....

✪ Write a nuclear equation to show the conversion of a neutron to proton.

....

✪ What is the electric charge of the particle (X).

....

Assessment Questions

First : Choose the correct answer :

1. If the nuclear binding energy of the helium nucleus equals 28 MeV, so the nuclear binding energy for each nucleon in the helium nucleus with the million electron volt equals ....

A. 7 B. 14

C. 56 D. 112

2. If the difference between the sum of the masses of the nucleus components of the iron atom and the nucleus mass when it's stable is 0.5 u , so the nuclear bond energy of the nucleus of the iron atom is ....

A. 0.8×10^{-19} MeV B. 0.5 Joule

C. 0.5 MeV D. 465.5 MeV

3. If the proton is converted into neutron .... is emitted

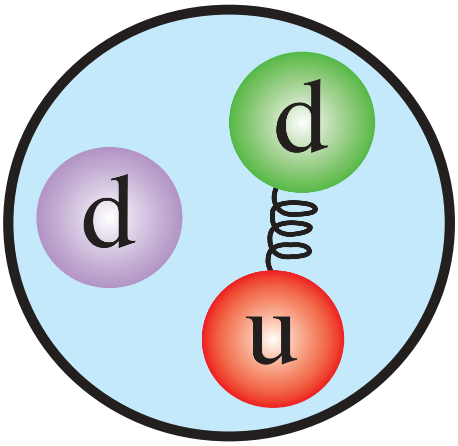
A. β^- B. β^+

C. α D. δ

4. The following drawing represents the structure of ....

A. Proton B. Neutron

C. Electron D. Meson



Second : solve the following problems :

Use the following relationships when needed:

Proton mass = 1.007825 u – neutron mass = 1.008665 u – speed of light = 3×10^{8} m/s

1 u = 1.66×10^{-27} kg

1. Use Einstein's formula to calculate the mass in kilograms that transforms into energy estimated to be 190 MeV.

2. Calculate the energy estimated in units of MeV resulting from the transformation of 5 g from a substance into energy.

3. Calculate the binding energy of the nucleus $^{4}_{2}He$ Estimated with MeV units and then calculate the binding energy for each nucleon in this nucleus if you knew that $^{4}_{2}He$ = 4.001506 u

4. Calculate the binding energy of the nucleus $^{16}_{8}O$ Estimated with MeV units and then calculate the binding energy for each nucleon in this nucleus if you knew that $^{16}_{8}O$ = 15.994915 u

5. Which are more stable: nucleus $^{16}_{8}O$ Or nucleus $^{17}_{8}O$ if you knew that:

$$^{16}_{8}O = 15.994915\ u\ ,\quad ^{17}_{8}O = 16.999132\ u$$

Third : Search and Learn :

Use the Internet in making a research to know the source or origin of the name 'quark' and who discovered these primary particles. What are the types of quarks? Write a research and show it to your classmates using the computer and the PowerPoint program.

Lesson Two : Radioactivity and Nuclear Reactions

Application Activity : Half-life of a Radioactive Substance

Purpose of the Activity

☑ Using the graphical relationship between time and the number of remaining nuclei in calculating the half-life span.

Acquired Skills

☑ Explaining terms – displaying data in a graph – reaching results .

Materials

☑ Graph paper.

Procedure :

- Given that: in an experiment to measure the half-life of a radioactive substance(radon $^{220}_{86}Rn$), the relation between the remaining nuclei (n) is in the million and the time (t) in seconds as in the following table:

t	0	10	20	30	40	50	55	60	65	70
n	30	26	23	21	18	16	15	14	13	12

- Required: draw a graphical relationship between the number of remaining nuclei (on the vertical axis) and time (on the horizontal axis) on a graph paper.

Analyzing the results and inferring :

- Calculate the half-life of the radioactive radon element.

....

- What is meant by the value of half-life that you obtained?

....

- In one of the stages of $^{220}_{86}Rn$ reduction by emitting an alpha particle:

A. What is the nature of alpha particles?

....

B. When an alpha particle emits from a nucleus of a radioactive radon -220, it transforms into a polonium isotope. Write the equation that represents this transformation.

Assessment Questions

First : Choose the correct answer :

1. One of the following properties is related to Gama rays ....

A. Have a positive charge
B. Have a negative charge
C. They are electrons
D. They are electromagnetic waves

2. If you know that ${}^{B}_{A}X$ represents a nucleus of an element emitting alpha particles, then the radiation of this element nucleus to alpha particles can be represented by the following equation: ....

A. ${}^{4}_{2}He + {}^{B+4}_{A+2}X \longrightarrow {}^{B}_{A}X$

B. ${}^{4}_{2}He + {}^{B-4}_{A-2}X \longrightarrow {}^{B}_{A}X$

C. ${}^{4}_{2}He + {}^{A-2}_{B-2}X \longrightarrow {}^{B}_{A}X$

D. ${}^{4}_{2}He + {}^{B-2}_{A-4}X \longrightarrow {}^{B}_{A}X$

3. In the equation ${}^{4}_{2}He + {}^{9}_{4}Be \longrightarrow {}^{12}_{6}C + X$ (X) is ....

A. Electron
B. Proton
C. Neutron
D. Gama ray

4. Thorium ${}^{228}_{90}Th$ Is converted into ${}^{216}_{84}Po$ as a result of releasing a number of alpha particles equals ....

A. 2
B. 3
C. 4
D. 5

5. X is a nucleus of a radioactive element losing 5 alpha particles respectively, as a result, its nucleus changed into the element nucleus ${}^{206}_{80}X$, so the nucleus of the origin element X is ....

A. ${}^{216}_{90}X$
B. ${}^{216}_{82}X$
C. ${}^{226}_{86}X$
D. ${}^{226}_{94}X$

6. One of the following properties is related to alpha rays ....

A. They are nuclei of helium

B. They have more ability to ionize the air

C. They have more ability to permeate in the air

D. They are affected by the magnetic field

7. After passing 12 minutes for a pure sample of a radioactive element , 75% of the atom nuclei of this element dissolve. The half-life of this element equals ....

A. 3 minutes
B. 4 minutes
C. 6 minutes
D. 9 minutes

Second : essay questions :

1. Compare alpha and Gama rays in the aspect of:

A. The charge of each

B. The ability of each to permeate the air

C. The ability of each to ionize the air

2. Radium $^{220}_{88}Ra$ is disintegrated to give an alpha particle. Show this reaction using a suitable nuclear equation.

3. Explain the four steps of the cell radiation damage.

4. Explain the harmful effects of the radiation emitted by the cell phone and lap top sets.

5. State the difference between:

A. Chemical reaction and nuclear reaction.

B. Nuclear fission and nuclear fusion.

C. Ionizing radiation and unionizing radiation.

Unit Five Revision Questions

First : Choose the correct answer :

1. .... are called nucleons

A. Protons and alpha particles
B. Alpha particles and beta particles
C. Beta particles and neutrons
D. Neutrons and protons

2. Which of the following characteristics is not related to the concept of the isotopes of the element ....

A. They have the same chemical properties
B. They have the same atomic number
C. They have the same number of neutrons
D. They have the same number of protons

3. The number of atoms of a radioactive element sample is $(4.8 \times 10^{12}$ atom$)$ and the half-life of this element is 2 years, the number of the atom nuclei of this element dissolved after 8 years equals ....

A. 2.4×10^{12}
B. 4.2×10^{12}
C. 3.6×10^{12}
D. 4.5×10^{12}

4. The Value of Q for a (u) quark is equal to ....

A. 0
B. + 1/3
C. + 2/3
D. -1

5. Which of the following particles is denoted by the symbol He^{4}_{2} ....

A. Alpha particle
B. Beta particle
C. Neutron
D. Proton

Second : answer the following questions :

1. Complete the following nuclear equations

A. $^{226}_{88}Ra \longrightarrow ^{4}_{2}He$ + ...

B. $^{9}_{4}Be$ + ... $\longrightarrow ^{12}_{6}C + ^{1}_{0}n$

C. $^{14}_{7}N + ^{4}_{2}He \longrightarrow ^{1}_{1}H$ + ...

Third : give the reason :

1. The actual mass of the nucleus of any atom is less than the total masses of its components.

....

2. The atomic number or mass number of a radiant nucleus does not change as Gama rays emit from it.

....

3. It is difficult to do the nuclear fusion reaction at the laboratories.

....

Fourth : solve the following problems :

1. Find the nuclear binding energy of the carbon nucleus $^{12}_{6}C$ estimated by:

A. The unit of atomic masses (u)

B. Million-electron volte (MeV)

....

....

2. The deuterium nucleus is called deuteron. The deuteron is composed of neutron and proton. If the mass of deuteron is 2.014102 u , the mass of proton is 1.007825 u and the mass of neutron is 1.008665 u .calculate the nuclear binding energy of the deuteron using MeV units.

....

....

3. Calculate the quantity of energy in joul, produced from converting 3 gm of mass into energy.

....

....

4. Calculate the amount of energy produced from converting 1.66 × 10-24 gm measured by:

A. Joul (J)

B. Million electron volte (MeV).

....

....

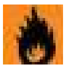
Safety Symbols

Follow up the precautions required as you use a device or chemical signed by the next safety symbols:

Safety goggles (always wear safety goggles).

Clothing protection (always wear the lab coat).

Corrosive chemical (use safety goggles , lab coat (apron) and do not touch chemicals).


Flames (for girls, tie back your loose hair, wear the lab coat (apron) to tighten your baggy clothes inside it and do not expose them to get burned).

Poison do not chew gum, drink or eat in the laboratory. Never place your hands near your face.

Electricity (be careful as you use an electrical device).

Danger of inhalation (do not inhale chemicals).

Danger of the thermal burning (do not touch hot objects with your bare hands).

Glass breakage (do not use breakable glass materials and do not heat the bottom of a test tube).

Disposal (get rid of the chemicals by following the instructions of each).

C Corrosive chemical substance.

I Irritant or harmful.

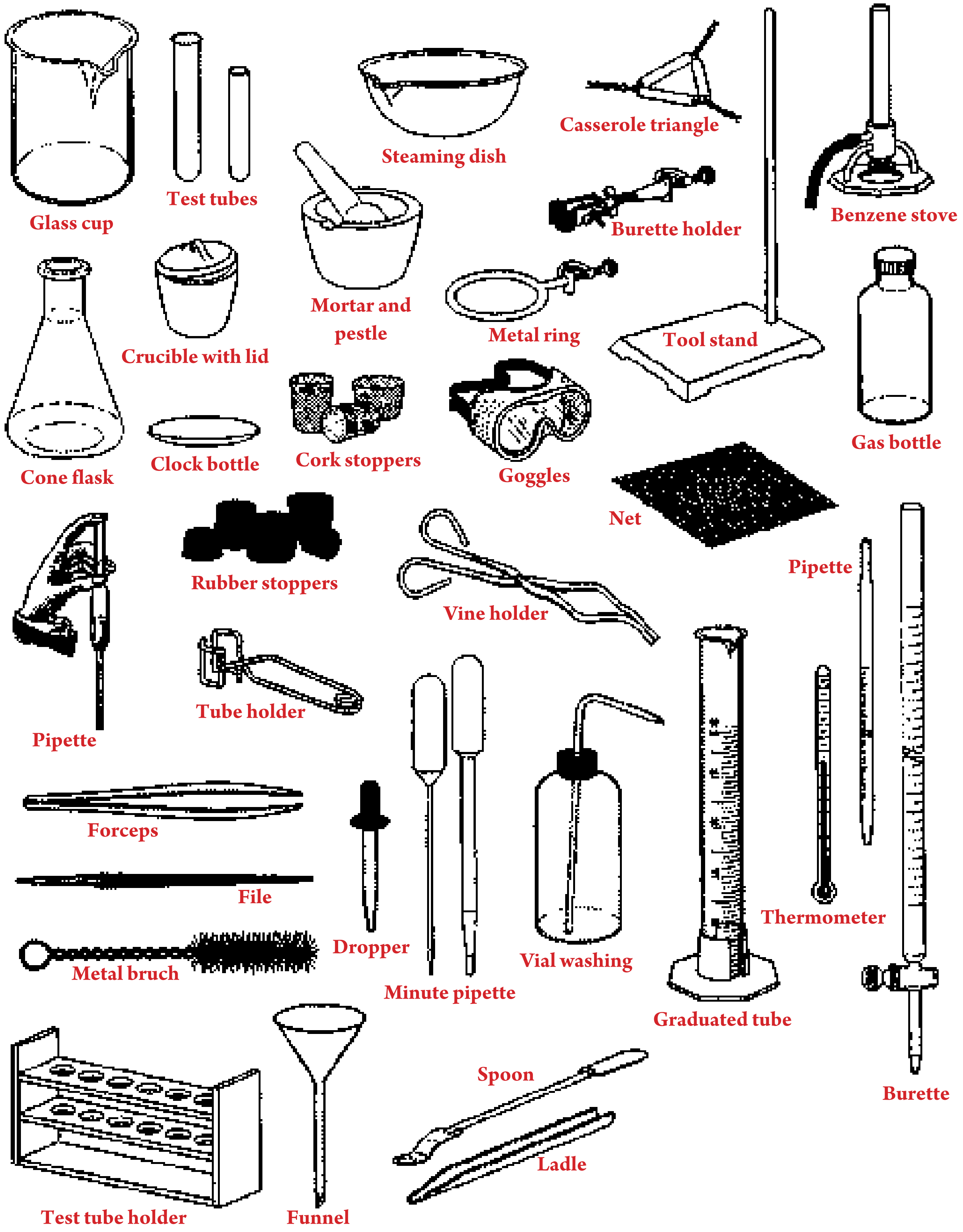
F Flammable.

T Toxic.

The summary of the steps that should be followed in case of the occurrence of some lab injures:

Injure	How to handle
Acid burns	Put the injured part under cold water for a continuous period, then use pads with bicarbonate salt.
Faint	Put the person in open air and place his head in a tilted position in a way that the head is in a lower position than all the body parts.
Burning	Close all the gas taps, plug all the electrical connections, use anti burning blanket and use the fire fighting to control the place.
Eye injure	Directly wash the eyes with water and do not rub the eye if it contains a strange object to avoid having wounds in the cornea.
Simple wounds	Let some blood bleed, then wash the wound with water and soap.
Poisoning	Tell your teacher about the substance used which causes the poisoning.

Lab Tools


Glass cup
Test tubes
Steaming dish
Casserole triangle
Benzene stove
Burette holder
Mortar and
pestle
Metal ring
Tool stand
Crucible with lid
Gas bottle
Cone flask
Clock bottle
Cork stoppers
Goggles
Net
Rubber stoppers
Vine holder
Pipette
Pipette
Tube holder
Forceps
File
Dropper
Metal bruch
Minute pipette
Vial washing
Thermometer
Graduated tube
Burette
Spoon
Ladle
Test tube holder
Funnel

Some general rules that should be followed as you use the lab tools :

Balance

- Put the dry substances in the balance pan only, while liquid substances should be weighed by the difference method.
- Close the balance doors during weight because this procedure prevent the error resulted from air currents.
- Put the substance you want to weigh in the middle of the balance pan.
- Clean the balance pan using your own brush.

Test Tubes

- Make sure that the test tube mouth is not pointed at your face and do not catch it by your hand as you heat it but you should use the holder.
- As you heat the tube, you should heat it from the bottom but not from the side. Use a quiet flame and continually move it to avoid getting broken due to high heat.

Graduated Cylinder

- As you pour the liquid in the graduated cylinder, you should wait until its surface settles.
- Put your eye at the horizontal level of the liquid surface, then read the value which matches the plane part of the liquid lunate surface.
- Write the number followed by the measuring unit written on the cylinder.

Pipette

- Do not heat the pipette holding it by your hand for a long time or approaching it to a heat source.
- Give enough time to the liquid to get out of the pipette completely.
- Do not shake or blow the pipette to force the liquid to get out.
- Do not lose any part of the liquid while you transfer it from the pipette.

Burette

- Fix the burette in a metal base stand to keep it vertical while you do the experiment.
- Fill the burette with the liquid above the graduation zero present near the upper end of the burette after you close the tap well, then open the tap to let the air below it go off until the liquid reaches the graduation zero and close the tap.
- As you read the graduations in the burette, your eye should be at the level of the liquid surface. The correct reading should be below the liquid concavity touching the high point of the graduation line that you need to measure.

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عدد الملازم بالغلاف	١١,٥ ملزمة
ورق المتن	٨٠ جم أبيض
ورق الغلاف	٢٠٠ جم كوشيه
طبع المتن	٤ لون
طبع الغلاف	٤ لون
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